

ELECTRICAL ENGINEERING RESEARCH

INTERIM REPORT NO. 1

LEAK DETECTION TECHNIQUE
IMPROVEMENT STUDY
FOR SPACE VEHICLES

NAS8-11199

April 1965

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University ATHENS
RESEARCH INSTITUTE



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April 27, 1965

Mr. C. P. McMurray, Purchasing Office, PR-EC
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama 35812

Dear Mr. McMurray:

Attached is the formal report submitted in fulfillment of Part B2, Article 1, of NASA contract number NAS8-11199. This report covers a period from April 7, 1964 to April 7, 1965, and covers all work which is in a satisfactory state for reporting.

As directed in Part B2, Article 1, aforementioned, this report in narrative form covers technical findings, study performed, evaluation of results obtained, conclusions and recommendations for future study and such other pertinent data developed during the period of the contract. The report also includes principles, proceedings, and methods of application that should be generally applicable to the utilization of results of the study.

An appreciable amount of the work described herein will be continued in the extension recently granted to the contract through April 7, 1966.

Sincerely yours,

R. C. Quisenberry, Director
NAS8-11199

Copy No. _____

Interim Report No. 1

OHIO UNIVERSITY
College of Engineering and Technology

LEAK DETECTION TECHNIQUE IMPROVEMENT STUDY
FOR SPACE VEHICLES

An Investigation and Study

for the

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Contract NAS8-11199

Athens, Ohio
April, 1965

ABSTRACT

An updating of the state-of-the-art in leak detection methods has been made and is reported. Since new devices continue to appear on the scene, this task is a continuing one. The literature research has also been updated and the information contained therein has been automatized by use of IBM cards. A set of approximately 4000 cards will be supplied upon completion of the bibliography classification for rapid retrieval of desired information.

The Time-Sharing Halogen Gradient Detector developed under this contract is described in detail. In addition, proposed methods of improvement in the standard G. E. Ionization Diode currently underway are described herein. The Vibrating Capacitor has also been under continuing investigation as a tracer gas detector. In addition, test results and conclusions concerning the use of the radioactive isotope, Americium 241, are described.

Acoustical methods for leak detection are being studied as described. This approach may well lead to a more sophisticated system to reinforce the presently operable tracer gas method. The identification of sound-injected energy by correlation detection methods looks promising at this point in the development. The state-of-the-arts survey indicates that the transistor microphone, which is a key element in the acoustical system, will soon be available.

Conclusions and recommendations are presented as the distillation of the suggestions which have come to light in the course of these investigations. It is hoped that these may result in real progress in the direction of the ultimate leak detector.

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CHAPTER I

INTRODUCTION

The work described by this report is a continuation of a task begun in January, 1962 under Contract NAS8-2563 and reported in the "First Formal Report" LEAK DETECTION TECHNIQUE IMPROVEMENT STUDY FOR SPACE VEHICLES in September, 1962, and also in the "Second Formal Report" LEAK DETECTION TECHNIQUE IMPROVEMENT STUDY FOR SPACE VEHICLES in June, 1963.

In brief, this work consisted of three main closely interrelated subtasks: (1) a thorough search of the literature, compiling a comprehensive bibliography and collecting abstracts of significant articles, (2) a state-of-the-art survey through investigation of information about existing or proposed leak detection equipment and techniques uncovered by the literature search, or found in advertisements in current technical publications, or by making inquiry, and (3) seeking means of improving existing techniques and/or developing new approaches based on ideas generated in the course of the investigations.

The results of subtask (1) under NAS8-2563 and its two extensions are presented in Chapter X, pages 157-258 of the Second Formal Report. As in any active field of research and development, the literature of leak detection is growing, and so must the bibliography. This growth is reported herein as Chapter II of this report.

The results of subtask (2) including semi-quantitative tests on a number of representative commercial devices appear in Chapters III, IV, V, VI, and VII

of the Second Formal Report. Since new devices continue to appear on the scene, and testing methods are being refined and revised, this also is a continuing effort. Chapter III of this report deals with this phase of the project.

Subtask (3), the development phase of the effort, involved three main stems, (a) improvement of tracer gas detectors, mainly the hot anode platinum diode halogen gun, (b) the study and development of acoustical methods, and (c) the systems approach.

Stem (a) was concerned with three problems: the elimination of background troubles, the reduction of possible hazards by reducing the operating temperature of the active element, and the miniaturization of the device to make it portable and independent of fixed power sources. This work was reported in Chapters IV, IX, and XII of the Second Formal Report. This project has been and is being continued under NAS8-11199 and is reported herein in Chapters V and VII.

Stem (b), acoustical methods involving historically the detection of the acoustical energy generated by the action of the leak itself, and more recently, the injection of tagged-sound energy into the system and its identification by correlation detection methods seems to offer considerable promise. Studies begun under NAS8-2563 and reported in Chapter VII of the Second Formal Report have been continued and are reported in Chapter VI of this Interim Report.

Stem (c) is reported in Chapter VIII of the Second Formal Report.

This First Interim Report, covering the period from April, 1964 to April, 1965 has four major Divisions.

Division A, including Chapters II and III, reports the Continuation and Refinement of the Literature Search and State-of-the-Art Survey.

Division B, including Chapters V and VII, reports the Development of a Prototype Time-sharing Halogen Gradient Detector.

Division C, including Chapter VI, reports Further Studies in Acoustical Methods.

Division D, consisting of Chapters VIII and IX discusses various Miscellaneous Research Projects and Feasibility Studies probing new methods, new approaches to old methods, and improvements of transducer elements now in use.

CHAPTER II

LITERATURE SEARCH and BIBLIOGRAPHY AUTOMATION

The search of the literature begun under NAS8-2563 which resulted in a bibliography with 816 entries* has been continued under NAS8-11199 with the addition of 250 new listings.

Experience in using the cards accumulated in compiling this bibliography has indicated the desirability of a certain amount of automation. To achieve this, each entry is being studied and placed on a 5 x 8 inch card like the one shown in Figure 1 and also on IBM cards having the formats shown in Figure 2 and Figure 3.

These IBM cards greatly facilitate sorting of the entries and automatic preparation of up-to-date bibliographies at any point in the development of the search.

As shown in the figures, each IBM card carries in columns 78, 79, 80 a number indicating the subject of the article. These numbers, together with the subject classification each indicates are displayed in Table I.

In order to indicate the source of the article columns 73, 74, 75 as indicated in Figures 2 and 3 carry a coded designation of the journal or government agency. In order that this listing be readily available, a third set of IBM cards has been punched which permits printing it out when needed. The format of these IBM cards is shown in Figure 4. A list of the useful journals is displayed as Table II.

* Second Formal Report, pages 159-223.

Blears, J.

J.Sci.Instr., Supl. 1 20-8 (1951)

00550

900

General Principles of Leak Detection

The techniques of leak detection are reviewed, special emphasis being placed on methods for obtaining high sensitivity with simple apparatus. A theoretical analysis of the gas flow problem is supplemented by experimental results obtained by using two diffusion pumps in cascade. The importance of using constrictions and correctly positioning the gage is stressed and the losses of sensitivity due to virtual leaks, leaks in series and by-pass methods are considered. The relative sensitivities of different leak detection methods are tabulated. (auth.)

Deals with mechanical, gage type, leak detectors where pressure differences in the entire system must be measured. No discussion is given to locating individual leaks, only showing if system is leak tight.

FIGURE 1

FORMAT USED FOR ABSTRACT INFORMATION CARDS SHOWING CROSS-REFERENCE NUMBER USED IN

IBM CLASSIFICATION AT TOP RIGHT

FIGURE 2

SAMPLE IBM: TITLE CARD SHOWING FORMAT OF CHARACTER BREAKDOWN

TABLE I

<u>Column</u>			<u>Subject classification or subclassification</u>
78	79	80	
1			Gas detectors
1	1		Thermal conductivity
1	1	1	Hot wire bridges
1	1	2	Thermistor bridges
1	1	3	Thermocouple devices
1	2		Combustion meters
1	2	1	Hydrogen detectors
1	3		Ionization detectors
1	3	1	Halogen guns
1	3	2	Halogen bridges
1	3	3	Ionization gauges
1	4		Electromagnetic detectors
1	4	1	Vibrating capacitors
1	4	2	Paramagnetic detectors
1	4	3	Ultraviolet resonant absorption detectors
1	4	4	Infrared resonant absorption detectors
1	5		Analyzers
1	5	1	Mass spectrometers
1	5	2	Miniature mass spectrometers
1	5	3	Chromatographs
1	5	4	Specialized chemical responders
1	6		Olefactory tracers
1	6	1	Mercaptans
1	6	2	Other compounds
2			Radioactive tracer methods
2	1		Radioactive gases
2	1	1	Kr85
2	1	2	Radon
2	1	3	Others
2	2		Detectors
2	2	1	Alpha detectors
2	2	2	Beta detectors
2	2	3	Gamma detectors
2	3		Health
3			Liquid leak detectors
4			Acoustical detection systems
4	1		Passive
4	1	1	Sonic listeners
4	1	2	Ultrasonic listeners (translators)

<u>Column</u>			<u>Subject classification</u>
78	79	80	
4	2		Active
4	2	1	Sonic injection
4	3		Active-passive
4	3	1	Sonic modulation of leak noise
4	4		Acoustical transducers
4	4	1	Audio microphones
4	4	2	Ultrasonic microphones
4	4	3	Semiconductor microphones
4	4	4	Seismic devices
4	4	5	Directional horns etc.
4	5		Related circuitry
4	5	1	Correlation detectors
4	5	2	Noise immunity circuits
4	5	3	Doppler shift sensitive devices
5			Pneumatic and hydraulic devices
5	1		Manometers
5	2		Diaphragms
5	3		Snap bubbles
5	3	1	Techniques
5	3	2	Solutions and mixtures
6			Gas Dynamics and Gas properties
6	1		Gas Dynamics
6	1	1	Nozzle dynamics for detectors
6	1	2	Gas flow and diffusion in closed pipes
6	1	3	Gas flow from and around leaks
6	1	4	Supersonic gas flow
6	2		Gas Properties
6	2	1	Densities
6	2	2	Diffusion properties
6	2	3	Ionization potentials
6	2	4	Other electromagnetic properties
7			Useful circuitry
7	1		Transistorization
7	1	1	Amplifiers
7	1	2	Level sensing circuits
7	1	3	Indicator circuits
7	1	4	Power supplies
7	1	5	Economizers
7	2		General circuitry
7	3		Molecular circuits
8			Devices related to leak detectors
9			Phenomena of possible applicability

TABLE II

Journal Listings

- 001 Acta Chemica Scandinavica
- 002 American Gas Journal
- 003 American Industrial Hygenic Association Journal
- 004 Analytical Chemistry
- 005 Analyst
- 006 Annual New York Academy of Science
- 007 Annales De Radioelectricite
- 008 Applied Scientific Research
- 009 Applied Spectroscopy
- 010 Archives Biochemistry and Biophysics
- 011 Australian Journal of Physics
- 012 Australian Journal of Chemistry

- 041 Biochemical Journal
- 042 Brennstoff-Chemie
- 043 British Journal of Applied Physics
- 044 British Journal of Applied Physics
- 045 Bulletin of Academy of Polotechnic Science
- 046 Bulletin Academy Royal Belgique Cl. Science
- 047 Bulletin of the Institute of Chemical Research, Kyoto U.
- 048 Bulletin Laboratory Chim. Provinciali

Journal Listings (Cont.)

049 Bulletin of the Society of Chimestry (France)

050 Bulletin of Society Science Bretagne

081 Cahiers de Physic

082 Canadian Journal of Physics

083 Canadian Journal of Research

084 Canadian Journal of Technology

085 Chemical Abstracts

086 Chemical Engineering

087 Chemical Engineering Progress

088 Chemical Metallurgy

089 Chemical Technology

090 Chemicke Listy

091 Chemicky Prumysl

092 Chemie

093 Chemiker-Zeitung

094 Chemistry in Canada

095 Chemistry and Industry

096 Chimia (Switz)

097 Chimestry and Industry (London)

098 Chimica et Industria

099 Ciencia

100 Civil Engineering

Journal Listings (Cont.)

101 Collection Czechoslov Chemical Communications

102 Colloid Chemistry

103 Comptes Rendus

121 Dechema Monograph

122 Dissertation Abstracts

123 Doklady Akadamy Nauk. SSSR

124 Drug and Cosmetic Industry

161 Electric Engineering

162 Electronic Industries

163 Electronic Technology

164 Electronic World

165 Electronics

166 Electrotech U. Maschinenbau

167 Elektrotechnik (Berlin)

168 Experimentia

201 Farm Science and Technology

202 Fonderie

241 Gas Age

242 Gas Chromatography

243 Gas Council Research Commu. (Eng)

Journal Listings (Cont)

- 244 Gas Journal
- 245 Gas und Wasserfröh
- 246 Gas World
- 247 General Electric Review

- 281 Hochvakuum-Technology
- 321 indian Journal of Physics
- 322 Industrial Design
- 323 Industrial Engineering Chemistry
- 324 Industrial Chemist
- 325 Industrial Chemistry Analytical Edition
- 326 Industrial Radio Engineering Proceedings
- 327 Instruments
- 328 Instruments and Control Systems
- 329 Instruments and Experimental Techniques
- 330 International Journal of Air Pollution
- 331 IRE Trans. of Industrial Electronics
- 332 Iron and Steel (Eng)
- 333 ISA Journal
- 334 Italia

Journal Listings (Cont.)

- 361 Japan Society Bulletin
- 362 Jet Propulsion
- 363 Journal of American Water Works Association
- 364 Journal of Applied Physics
- 365 Journal of Basic Engineering
- 366 Journal of Chemical Education
- 367 Journal of Chemical Physics
- 368 Journal of the Chemical Society
- 369 Journal of Colloid Science
- 370 Journal of Franklin Institute
- 371 Journal of Inst. Electronic Engineers
- 372 Journal of Industrial Fuel
- 373 Journal of Oil and Colour Chemists
- 374 Journal of Optical Society of America
- 375 Journal of Physical Radium
- 376 Journal of Physics Society of Japan
- 377 Journal of Royal Institute of Chemistry
- 378 Journal of Scientific Instruments
- 379 Journal of Scientific Instruments Supply
- 380 Journal of Technical Physics U.S.S.R.
- 381 Journal of Thoracic and Cardiovascular Surgery

Journal Listings (Cont.)

- 401 Kerntechik
- 402 Kolloid Zhur

- 441 Laboratoire Mediterranee de Recherches Thermodynamiques (France)
- 442 Laboratory Science
- 443 Le Vide (in French)

- 481 Magyar Kemiai Folyoirat
- 482 Makromolecular Chemi
- 483 Manufacturing Chemist and Pharmaceutical and Fine Chemical Trade Journal
- 484 Metallurgia

- 521 National Engineer
- 522 National Nuclear Energy Service
- 523 National Symposium on Vacuum Technology
- 524 Nature (London)
- 525 Nuclear Engineering
- 526 Nucleonics
- 527 Nuovo Cimento

- 561 Oil and Gas Journal
- 562 Oyo Butsuri

Journal Listings (Cont.)

- 601 Paper Trade Journal
- 602 Petroleum Engineering
- 603 Pharmazie
- 604 Philips Technical Review
- 605 Philosophical Magazine
- 606 Physica
- 607 Physica, 's Grav.
- 608 Physical Methods in Chemical Analysis
- 609 Physical Review
- 610 Physical Society of London. Rep. Progress Physics
- 611 Physics Today
- 612 Power
- 613 Process of the Cambridge Philosophical Society
- 614 Process International Philoel. Congress
- 615 Process of the Pennsylvania Academy of Science
- 616 Proceedings of Physical Society
- 617 Product Engineering

- 681 Record of Chemical Progress
- 682 Refrigeration Engineering
- 683 Research Engineering
- 684 Review of Scientific Instruments
- 685 Ricerca Scientifica

Journal Listings (Cont.)

- 686 Rivista Dei Combustibili

- 721 Science
- 722 Siemens-Zeitschrift
- 723 SlaboproudyObzor
- 724 Southern Power and Industry
- 725 Suddent Apoth. Ztg.
- 726 Suomen Kemistilehti

- 761 Termotecnia
- 762 Transaction Americam Society of Mechanical Engineering
- 763 Transactions Electrochemical Society
- 764 Transactions of the Faraday Society
- 765 Transactions of the Instrument Measure Conference (Stockholm)

- 801 U. S. Patent Department
- 802 Uspekhi Fiz Nauk

- 841 Vacuum
- 842 Vacuum Techniques
- 843 Vacuum Testing Handbook for Columbia Project
- 844 Vacuum-Technology (Brit)
- 845 Vide

Journal Listings (Cont.)

- 881 Water and Sewage Works
- 882 Water and Water Engineering
- 883 Welding Journal
- 884 Westinghouse Engineering
- 885 Wiadomosci Chemistry
- 886 World Oil

- 961 Zavodskala Laboratoriya
- 962 Zeitschrift Angewandte Physik
- 963 Zeitschrift fur Elektrochemie
- 964 Zeitschrift fur Instrumentenkunde
- 965 Zeitschrift fur Naturforschung
- 966 Zeitschrift fur Physik
- 967 Zhurnal Tekhnicheskoi Fiziki

CHAPTER III

STATE-OF-THE-ART SURVEY

Figure 4a reproduces the letter sent out to over 300 educational institutions, commercial companies, research laboratories, and private individuals who were thought to have been active in leak detection and closely related fields. About 100 replies were received, 46 of which supplied useful information. These sources are to be catalogued on IBM cards along with indexing as to the type of information available.

Table III is an alphabetic listing of these sources.

Table IV lists leak detection devices which for the most part have come to the attention of this study since completion of the Second Formal Report.

SAMPLE LETTER OF INQUIRY

The Ohio University Engineering Department is engaged in research on leak detection for the National Aeronautics and Space Administration with special emphasis on gas-pressurized plumbing systems from zero up to about 2000 psia.

At present our main avenues of attack consist of a halogen bridge detector, which will locate leaks by a gradient sensing action, and a sound injection system in which a mechanical driver is used to supply a signal of known frequency, and leaks are found by detecting this frequency outside the closed system.

Our files show that your laboratories have been working on leak detection research in the past. We would appreciate any information that you can supply on recent work done on any phase of leak detection, and especially on the methods and conditions mentioned above.

Thank you; for your consideration on this matter.

Sincerely,

G. E. Smith,
Assistant Director
NAS8-11199

GES/lb

TABLE III

- * Aertronic Associates, Inc.
Suite 503
11 W. Monument Ave.
Dayton 2, Ohio (Fredrick Harris)
- * Aircraft Armaments Inc.
Cockeysville, Md.
- * Air Force Flight Dynamics Lab.
Research and Technology Division
Air Force Systems Command
Wright-Patterson Air Force Base
Dayton, Ohio (Thomas S. Rice)
- * American Gas Association
605 Third Avenue
New York 16, N. Y. (Mr. Thomas Lee Roby - Research Coordinator)
- * American Oil Co.
Research and Development Dept.
Whiting Laboratories
2500 New York Avenue
P. O. Box 431
Whiting, Ind. (I. Ginsburgh)
- * Argonne National Lab. (Reports)
9700 S. Cass Ave.
Argonne, Ill. (Sophie V. Stephens)
- * Aro, Inc.
Arnold Air Force Station
Tenn. (S. D. Ansley, Jr.)
- * Atomic Energy of Canada Ltd.
Reactor Research Div.
Chalk River Project
Chalk River, Ontario, Canada (D. G. Hurst)
- * Indicates working in area of special interest to this project.

- * Babcock and Wilcox Co.
Research and Development Div.
1562 Beeson St.
P. O. Box 835
Alliance, Ohio (W. Markert, Jr.)
- * Bacharach Industrial Instrument Co.
200 N. Braddock Ave.
Pittsburgh, Pa.
- Barnes Engineering Co.
30 Commerce Rd.
Stamford, Conn. (Melvyn Canin)
- * Batelle Memorial Institute
505 King Avenue
Columbus, Ohio (R. B. Filbert, Jr.)
- Bausch and Lomb Inc.
Rochester 2, New York (W. F. Coombs)
- * Cambridgeshire College of Arts and Technology
Head of the Science Dept.
Cambridge, Eng.
- Cook Heat Treating Co.
P. O. Box 9463
Houston 11, Texas (J. R. Cook)
- * Delcon Corp.
Palo Alto, Calif.
- * Dept. of National Defense
Defense Research Board
Canadian Armament Research and Development Est.
P. O. Box 1427
Quebec, P. Q. Canada (G. H. Tidy)
- Dept. of The Navy
Bureau of Naval Weapons
Washington, D. C. (A. R. Press)
- * Indicates working in area of special interest to this project.

- * Dept. of The Navy
Bureau of Ships
Washington 25, D. C. (E. R. Meyer, Capt., USN)
- * Detroit Edison Co.
2000 Second Avenue
Deiroit 26, Mich. (J. M. Decker)
- Deutsche Versuchsanstalt Fur Luft Fahrt E. V.
Institut Fur Raum Fahrt Forschung, Germany (P. Kleber)
- * Dr. Arnold L. Ducoffe
Acting Director of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Ga.
- * E. I. du Pont de Nemours and Co., Inc.
Wilmington, Del. (F. B. Hill, Jr.)
- Esso Research and Engineering Co.
P. O. Box 45
Linden, N. J. (Dolores D. Kresge)
- Ford Motor Co.
20000 Rotunda Ave.
Dearborn, Mich. (Tom Westerlin)
- * General Electric Co. Research Dept.
Box 1072
Schenectady, N. Y. (S. Sturges)
- * Geophysics Corp. of America
Physics Research Div.
Bedford, Mass. (A. E. Barrington, Ion Physics Dept.)
- Georgia Institute of Technology
Atlanta, Ga. (R. L. Bullock)
- Gulf Research and Development Co.
P. O. Drawer 2038
Pittsburgh 30, Pa. (Gary Muffly)
- * Indicates working in area of special interest to this project.

- * Her Majesty's Stationary Office
York House
Kingsway, London, W. C. 2, Eng.
- * Honeywell, Inc.
Research Center
500 Washington Ave. S.
Hopkins, Minn. (L. P. Levine, Prin. Res. Sci.)
- Imperial Chemical Industries, Ltd.
P. O. Box 42 Hexagon House
Blackley, Manchester 9, Eng.
- Johns Hopkins University
Applied Physics Lab.
8621 Georgia Ave.
Silver Springs, Md. (B. H. Buckingham)
- Kansas University
Department of Physics
Lawrence, Kansas (J. D. Stranathan)
- Lincoln Labs.
Mass. Institute of Technology
Lexington, Mass. (Janet M. Campbell)
- * Long Island Lighting Co.
175 Old Country Road
Hicksville, N. Y. (A. C. Sugden)
- * Louisiana State University
Baton Rouge 3, La. (Jesse Coates)
- Mass. Institute of Technology
Dept. of Mechanical Engineering
Cambridge 39, Mass. (E. S. Taylor)
- National Chemical Labs.
Teddington, Middlesex, Eng. (F. G. Lanc)
- * National Physical Labs.
Aerodynamics Div.
London, Eng.
- * Indicates working in area of special interest to this project.

- * National Research Council
Technical Information Service
Ottawa 2, Canada (T. P. Houlding) Inq. no. 58068

New York University
Research Div.
University Heights
Bronx 53, N. Y. (D. S. Tracy)

- * Dr. C. E. Normand
Route 17 Gwinn Rd.
Knoxville, Tenn.

NRC Equipment Corp.
160 Charlemont St.
Newton, Mass. (P. R. Forant)

- * Oak Ridge National Lab.
Nuclear Div.
P. O. Box X
Oak Ridge, Tenn. (N. T. Bray)

- * Office of Technical Services
Dept. of Commerce
Washington 25, D. C. (E. J. Anderson, Chief)

- * Ohio State University
Engineering Experimental Station
156 W. 19th St.
Columbus, Ohio (R. J. Tait)

Pennsylvania State University
University Park, Pa. (R. H. Ramsey)

- * Peoples Gas, Light, and Coke Company
45 E. Pershing Rd.
Chicago, Ill. (F. C. Whiting)

Phillips Petroleum Co.
Bartlerville, Okla. (D. C. Smith)

- * Indicates working in area of special interest to this project.

- * Purdue University
Mechanical Engineering
Lafayette, Ind. (P. E. Liley)
- * Radio Corp. of America
Defense Electronic Products
Camden 2, N. J. (M. L. Feistman)
- Rocketdyne
6633 Canoga Ave.
Canoga Park, Calif. (R. J. Thompson, Jr.)
- * Shell Development Co.
Emeryville, Calif. (V. N. Smith)
- * Southern Union Gas Co.
P. O. Box 1692
Albuquerque, New Mexico (W. V. Gilpin)
- Standard Development Co. Ltd.
Crown House, Morden, Surrey, Eng. (H. N. Sheer)
- * Standard Telephone and Cables Ltd.
Footscray, Sidcup, Kent, Eng. (G. B. Thomas)
- * Stanford Research Institute
Menlo Park, Calif. (R. F. Muraca)
- Sylvania Electronic Products Inc.
Products Division Labs
Warren, Pa.
- Tennessee Eastman Corp.
Kingsport, Tenn. (E. V. Mortin)
- * Union Carbide Corp.
Nuclear Div.
P. O. Box P
Oak Ridge, Tenn.
- * Indicates working in area of special interest to this project.

- * United Kingdom Atomic Energy Authority
Atomic Weapons Research Est.
Aldermaston, Berkshire, Eng.

- U. S. A. F. Air Research and Development Comm.
Griffiss Air Force Base
Rome Air Development Center
Rome, N. Y. (B. F. Collier)

- * Air Force Systems
Foreign Technology Div.
U. S. A. F.
Wright Air Development Center
Dayton, Ohio (E. T. de Jonckheere)

- U. S. Army Electronics Command
Fort Monmouth, N. J. (L. Rokaw)

- * U. S. Dept. of Commerce
Patent Office
Commissioner of Patents
Washington 25, D. C.

- * U. S. Government Printing Office
Division of Public Documents
Washington 25, D. C. (C. W. Buckley)

- U. S. Naval Applied Science Lab.
Naval Base
Brooklyn, N. Y. (A. R. Allison)

- * U. S. Naval Ordinance Lab.
Silver Springs, Md. (G. Stathopoulos)

- * U. S. Naval Research Lab.
Washington, D. C. (W. A. Zisman)

- * U. S. Naval Weapons Lab.
Dahlgren, Vir.

- United Technology Center Quarterly Technical Report
Sunnyvale, Calif. (A. G. Cattaneo)

- * Indicates working in area of special interest to this project.

The University Western Bank
Sheffield 10, Eng. (H. D. Turner)

University of Cambridge
Engineering Lab.
Trumpington St.
Cambridge, Eng. (S. L. Harris)

University of Illinois
Coordination Science Lab.
Urbana, Ill. (W. C. Prothe)

University of Pittsburgh
501 Engineering Hall
Pittsburgh, Pa. (W. R. Turkes)

University of S. California
Engineering Center
Los Angeles, Calif. (N. Murray)

University of Uppsala
Fysiska Institutionen
Uppsala, Sweden (I. Lindgren)

* Vacuum-Electronics Corp.
Terminal Drive
Plainsview, N. Y.

* Westinghouse Electric Corp.
Scientific Equipment Dept.
Box 8606
Pittsburgh, Pa. (A. G. Mulier)

* Indicates working in area of special interest to this project.

TABLE IV
COMMERCIALY AVAILABLE LEAK DETECTORS

<u>Manufacturer</u>	<u>Detector Type</u>	<u>Gases Detected</u>	<u>Sensitivity</u>
Aero-Vac Corp.	Ionization Gauge Control Model AGC-1	-----	-----
Aero-Vac	Mass Spectrometer Tubes Model AST-1	-----	10^{-10} torr for N ₂
Aero-Vac	Vacuum Analyzer Model AVA-1	-----	10^{-10} torr for N ₂
Bacharach Industrial Instruments Co.	Gas Leak Detector Model SA-63	Halogens, argon, etc.	1/2 oz F-12 per year
Beckman Corp.	Infrared Analyzer Model 15-A	-----	-----
Davis Company	Flame Ionization Detector	Combustables	-----
Delcon Corporation	Ultrasonic Translator Detector	-----	----- **
Dept. of National Defence (Canada)	Speedivac Leak Detector	-----	-----
Gas Purifying Materials Co.	Analograph	(gas identification)	
General Electric	Halogen Leak Detectors Types H-2, H-3, H-4, H-5P, H-7	Halogens	1×10^{-9} std. cc/sec
General Electric	Mass Spectrometer Leak Detector Model M-60	Helium	5×10^{-11} cc/sec
General Radio Co.	Sound and Vibration Analyzer Model 1654-A	-----	-----
Honeywell Corp.	Vapor Detector Perchloroethylene Model	Almost all vapors	10 ppm for perchl.

** depends on pressure

<u>Manufacturer</u>	<u>Detector Type</u>	<u>Gases Detected</u>	<u>Sensitivity</u>
Loenco Inc.	Automatic Process Gas Chromatograph Model 160	-----	-----
Loenco Inc.	Dual Hydrogen Flame Ionization Detector	-----	-----
Loenco Inc.	Hi-Flux Gas Chromatograph Model 70	-----	-----
Loenco Inc.	Gas Chromatograph Model 154B	-----	-----
Loenco Inc.	Hydrogen Flame Ionization Detector	-----	-----
Loenco Inc.	Thermo Conductivity Detectors	-----	-----
Mine Safety Appliances Co.	M.S.A. Portable Billionaire Trace Gas Analyzer	Halogen, etc.	10 ppm for F ₁₂
N.R.C. Equipment Co.	Thermister-Bridge Gas Leak Detector	-----	-----
N.R.C. Equipment Co.	High Sensitivity Halogen Leak Detector	Halogen	10 ppm for F ₁₂
Shell Development Co.	Negative Ion Gas Detector	-----	-----
Union Carbide Corp.	Production Leak Rate Detection System	Helium	Continuous Monitor
U.S. Naval Research Laboratory	NRL Thermister Bridge Gas Leak Detector R05-19	Helium	0.001 cu. ft. per hour
Universal Controls Corp.	Dragnet Leak Detector	-----	-----
Usen Corp.	Usen Diffusion Leak Detector (Commercial version of NRL Thermister Bridge Detector)	Helium	0.001 cu. ft. per hour

<u>Manufacturer</u>	<u>Detector Type</u>	<u>Gases Detected</u>	<u>Sensitivity</u>
Vacuum Electronics Co. (Veeco)	Helium Leak Detector	-----	-----
Vacuum Electronics Co. (Veeco)	Residual Gas Analyzer	-----	-----
Vacuum Electronics Co. (Veeco)	Ultra-Sensitive Leak Detector Model MS U15 (Mass Spect.)	Helium	5×10^{-14} cc per sec
Westinghouse Corp.	Electronegative Gas Detector	SF ₆ and common refrigerents	0.1 ppm in air
Westinghouse Corp.	Oxygen Gauge (t.b.99-251)	Oxygen	ppm on a scale from 1 to 2000 psi

J.E. Lovelock
Anal. Chem. 33,
162, 1961

Electro-Capture Detector
(to our knowledge has not yet
been advertised commercially)

CHAPTER IV

LEAK DETECTOR TESTING FACILITY

The final evaluation of any instrument must be made by the ultimate user and will reflect not only the physical functioning of the device itself but also the complex of all those interfacial problems arising from operator psychology and environmental interactions. In pursuing state-of-the-art investigations we have made evaluations in as realistic a context as possible. It is very difficult under these conditions to obtain highly quantitative data since all the variables are statistical in nature and reliable measurements can be obtained only by repeated use and statistical analyses of sufficient samples of data. This would seem to lead to the conclusion that the best testing laboratory is the missile test floor itself - it does not, however, preclude the usefulness, desirability, or even the necessity of having an auxiliary laboratory in which conditions may be rigorously controlled. It is with this in mind that work has been started on setting up such a laboratory here.

In addition to the samples of leaking plumbing and the calibrated orifice leaks already in use, this laboratory will contain a means of supplying freon-air and other gas-air mixtures of precisely controlled and known composition. Available calibrated leak devices, such as the G. E. test leak, supply leaks of known rate but give very little control over background or tracer gradients. In order to obtain reproducible data for determining meaningful parameters of sample ingesting leak detectors, it is necessary to be able to supply the instrument being tested with reasonably large volumes of known tracer-air mixtures at atmospheric pressure. There must be no interference with the free flow of mixture into the instrument probe

and no accidental admixture with ambient air, contaminated with background or otherwise. For testing of gradient-sensitive instruments there must be two such sources of mixture so related that the difference in concentration is precisely known. It may also be desirable to have a third source for making tests on some instruments to evaluate the effects of ducting instrument exhausts in producing feedback responses.

In the early stages of the study of new transducers such as the hot ceramic diode* and the Americium 241 powered detector**, use was made of a chamber consisting of a vacuum plate and bell jar as shown in Figure 5 and Figures 75 and 76, page 139 of the Second Formal Report. This chamber is quite adequate for testing the response of the unmounted transducer to various concentrations of tracer; however, it is impossible to adjust rates of flow across electrode surfaces or to measure the gradient sensitivity, since this involves the difference between sensitivities to almost identical concentrations.

In use, the bell jar works on the very simple and accurate principle of partial pressures. An example will illustrate its operation. It is desired to test a transducer in a mixture of one part freon to a million parts air. The pressure in the chamber is first reduced to, say, 0.9 atmospheres. Pure freon is then added to bring the pressure back to 1.0 atmospheres. The mixture is now 10% (by volume) freon. If the pressure is now reduced to 0.1 atmospheres and air added to bring it back to 1.0 atmosphere, the concentration will be reduced to 1.0% freon by volume. This process may then be repeated until the desired concentration is reached - in this case four more times. Care must be exercised, of course, to see that thorough mixture of the freon and air is achieved. Even though the freon

* Refer to Second Formal Report, pages 131 to 139.

** Refer to this report, Chapter IX.

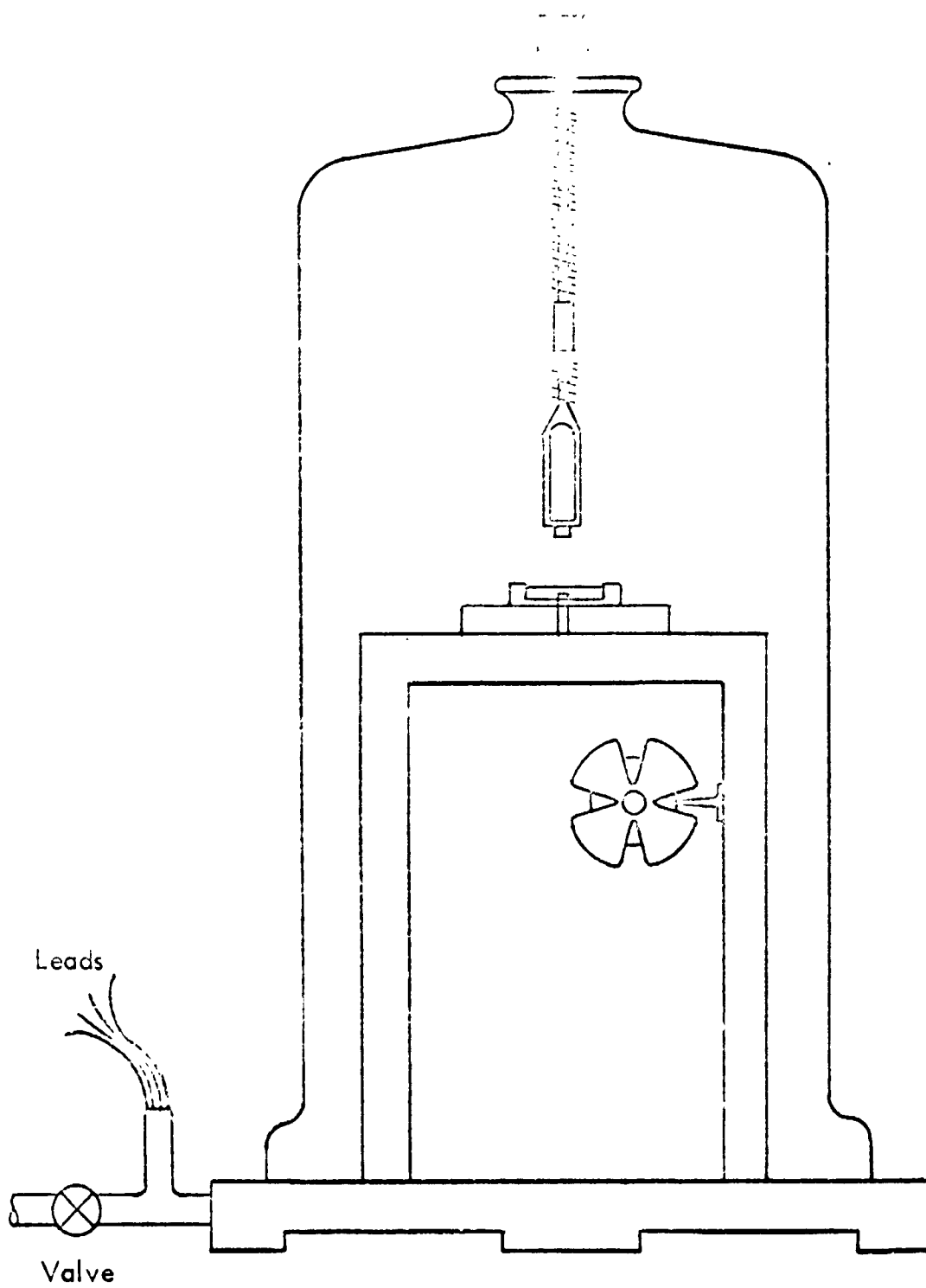


FIGURE 5

BELL JAR FOR TESTING TRANSDUCERS

is considerably heavier than air, there will be no tendency for settling out once complete admixture has been achieved*. Other final compositions may be had by applying the following formula:

$$\% \text{ Tracer} = 100 (1 - p_1) \prod_{i=2}^n p_i$$

where p_1 is the pressure to which the system is reduced before addition of the freon and the p_i are the pressures to which the mixture is reduced before adding the air. The symbol π indicates that the product of the pressures indicated is to be taken. All pressures are to be expressed in per unit of ambient atmosphere. Obviously it is necessary to be very careful about thorough mixing and to permit the temperature to stabilize before measuring pressure. If it is desired, for any reason, to set up a mixture of a certain percent by weight rather than by volume, the above formula is multiplied by the ratio of molecular weights of tracer and air.

Certain unavoidable errors in the measurement of pressure and temperature make it impossible to use the repeated dilution method for preparing samples of mixture differing by small increments of tracer concentration for use in testing gradient sensitive leak detectors. For this purpose it is necessary to prepare a single sample of the desired background level of concentration, divide it into two samples and then add freon to one or air to the other sample to produce the desired precise difference. The apparatus designed and presently being constructed for doing this is shown in Figure 6. The apparatus will consist of two pressure tanks, A and B in the figure, a water gasometer, C and D, for metering freon into the

* Refer to Second Formal Report, page 260.

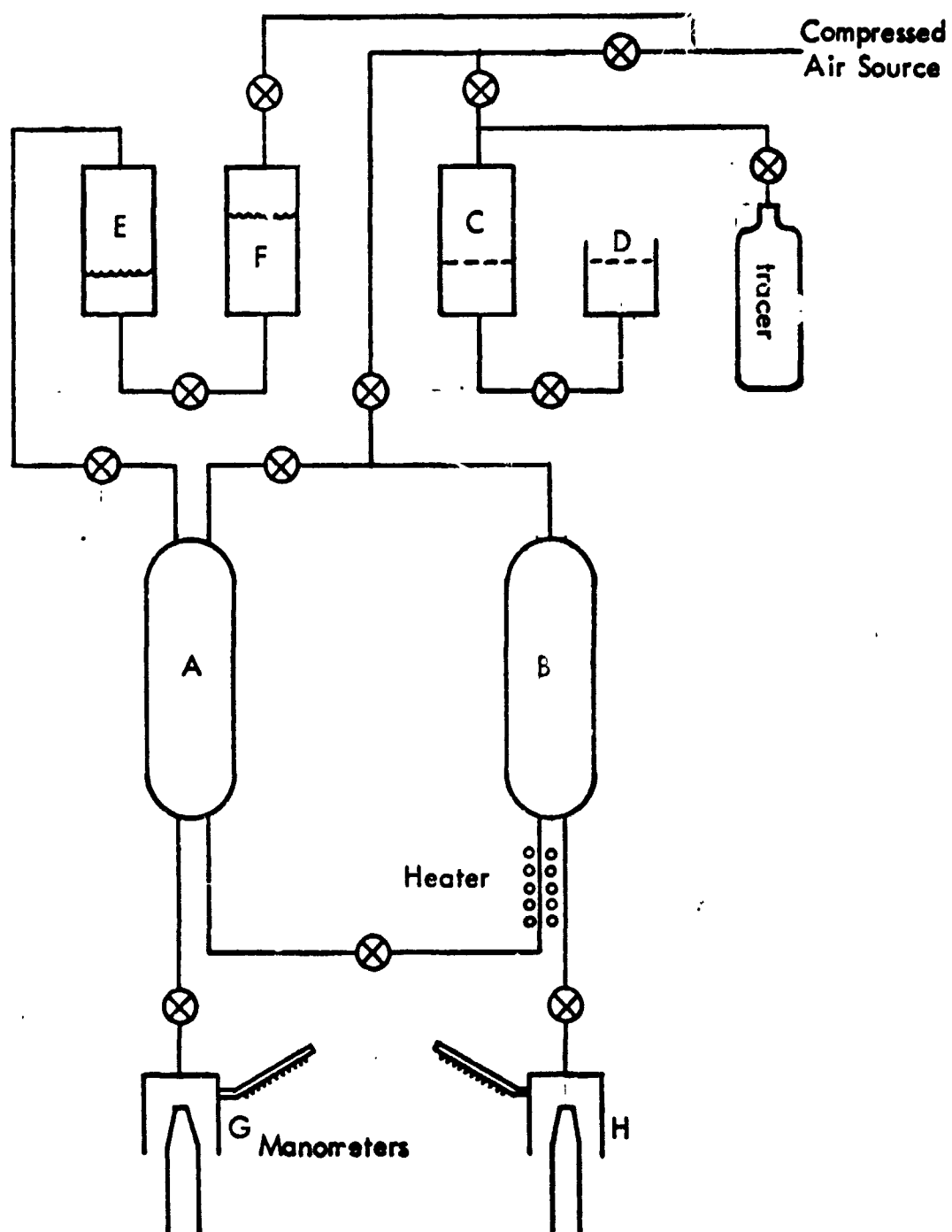


FIGURE 6

PROPOSED TEST APPARATUS

tanks, and an oil gasometer, E and F, together with associated valves and lines and two hoods with inclined manometers, G and H. Procedure for using the differential concentration apparatus is:

- 1) Flush all previous gas mixture from the system with compressed air.
- 2) Fill chamber C with tracer to be used from bottle or other source.
- 3) Using D insert desired amount of tracer into system.
- 4) Pressurize and mix both pressure tanks. Heater shown on line below tank B may be used to insure thorough mixing by causing convectional circulation of the mixture through tanks A and B and their associated lines.
- 5) Isolate tanks A and B by means of the appropriate valves.
- 6) Insert desired amount of air into tank B by means of pressure gasometer E and F.
- 7) Compute the concentration of tracer in A and B and the difference of concentration caused by the air last inserted in B.
- 8) Insert probes of detector to be tested into the hoods G and H and adjust the flow from pressure tanks A and B so that the inclined manometers attached to the hoods show a very small pressure differential above atmospheric ambient.

Operation as indicated above will insure a supply of tracer air mixture to both probes having the desired background level and a precise difference in concentration of tracer. The maintenance of a very small pressure above atmosphere insures that the gun will pump in sample in a natural manner and at a rate not affected by the apparatus used in the testing.

In addition to furnishing the means for making controlled tests on two probe detectors (gradient sensing), this set up will be useful in more rapid testing of single probe guns since it will allow preparation of samples of two different concentrations at the same time. Techniques will be developed as experience with the method is gained which will permit rapid testing with a high degree of quantitative accuracy.

CHAPTER V

TIME-SHARING HALOGEN GRADIENT DETECTOR

This system of leak detection and location, using freon concentration measuring equipment, suffers from background contamination difficulties. Freon, being a heavy gas, exhibits troublesome pooling effects. To overcome the attendant reduction of sensitivity of detectors responding to total halogen concentration, use may be made of time-derivative action by inserting a capacitor in the current measuring circuit to block out the average (dc) component. A halogen (freon) gun so operated (automatic zero mode, auto balance mode) may be made to give a rough space gradient indication by moving its probe uniformly through the air. However, this requires considerable skill and may also, if high velocity is used in an attempt to increase sensitivity, disturb the distribution it seeks to investigate.

Under Contract NAS8-2563, a two-diode halogen gradient sensitive bridge was developed and tested. This instrument proved to be capable of locating small leaks in the presence of background so strong that the ordinary halogen gun was saturated (off scale) on its least sensitive range. These experiments are described on Page 47 of the Second Formal Report.

A serious problem with the practical realization of the advantages of this bridge results from the differences in response curves of the individual diodes, and especially from their different rates of aging. This necessitates constant rebalancing of the bridge for each different background and for each time of use. In order to overcome this difficulty, the time-sharing halogen gradient detector was developed.

This detector ingests samples through two probes at slightly different locations, either right and left probes, or fore and aft probes may be used. The probes are connected to the diode through a gating valve which causes the diode to accept samples alternately from each probe. When the two probes are in the same halogen concentration, the samples seen by the diode are identical, and a constant (dc) current results. Where one probe takes in stronger halogen concentration than the other, as it must if a gradient is present and not normal to the probe to probe axis, the diode current will have an ac component. This ac component is separated from the dc component and amplified to give the gradient signal. A prototype instrument was built and checked out. Experience with this first model led to design changes in the circuitry and the building of two more prototype detectors. These two improved circuits have been delivered to NASA in Huntsville for further experimentation. The manuals delivered with these detectors are reproduced (with slight changes) below for completeness.

THEORY OF OPERATION

(The following discussion refers to the block diagram of Figure 7 and the circuits of Figures 8, 9, 10, 11, 12, 13, 14, and 15.)

The current of the platinum diode, which is alternately a measure of the freon concentration entering each of the two probes, is first amplified in the dc stage Q_1 . The resistance in series with the base of Q_1 is for protection against possible shorts in the diode which would apply the high anode voltage to this element, destroying the transistor. The second dc stage, Q_2 , serves to drive the background meter, M_1 , and as input for the Schmitt trigger, Q_{11} Q_{12} , which powers the sonalert background alarm, S .

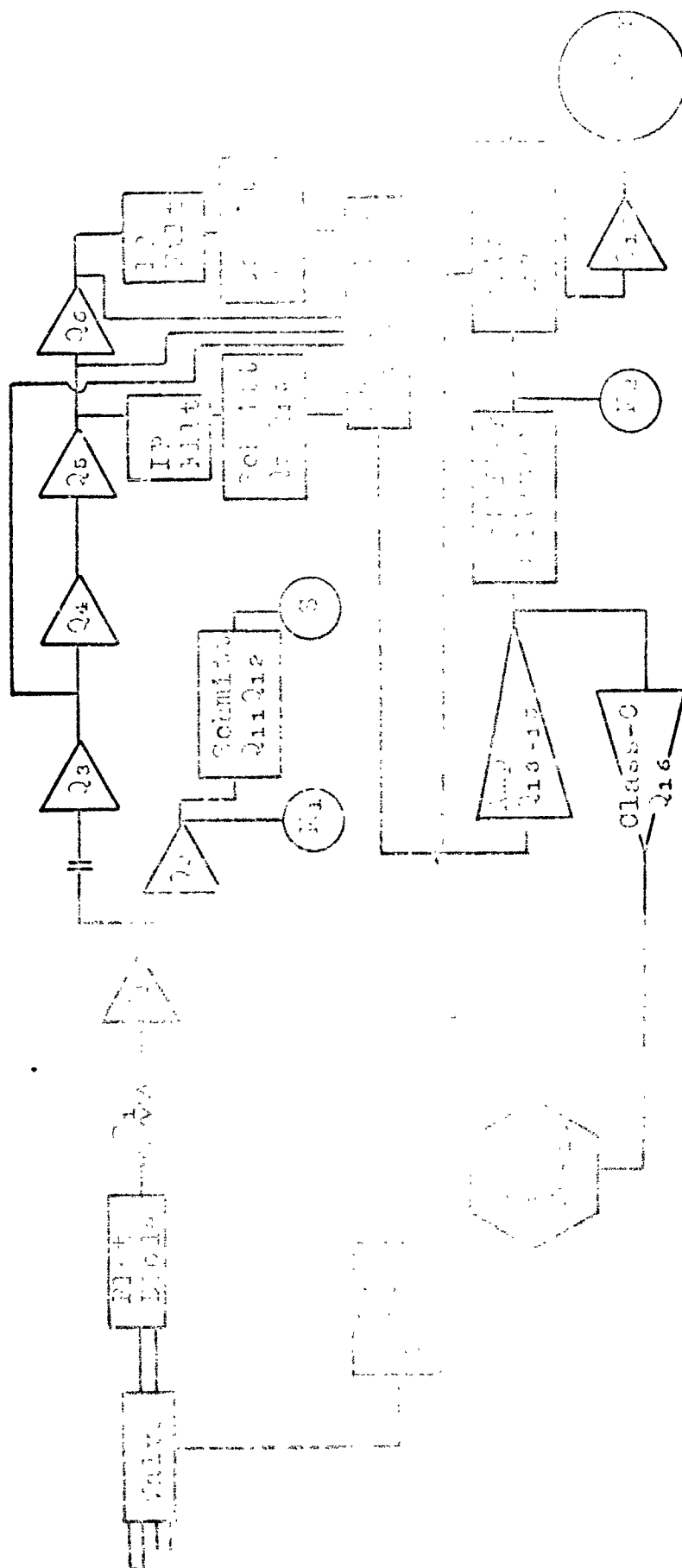


FIGURE 7
BLOCK DIAGRAM

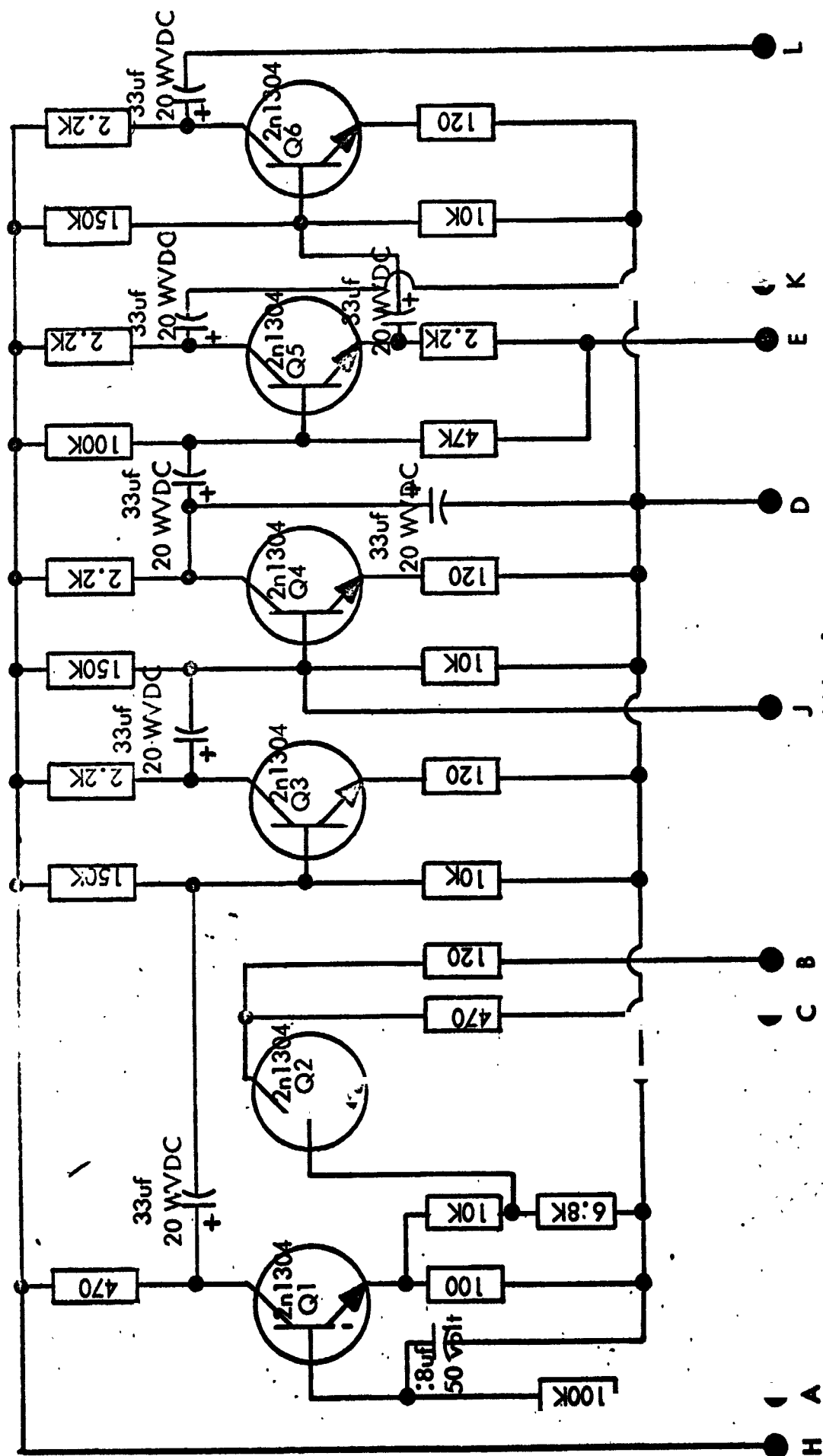


FIGURE 8
MAIN AMPLIFIERS

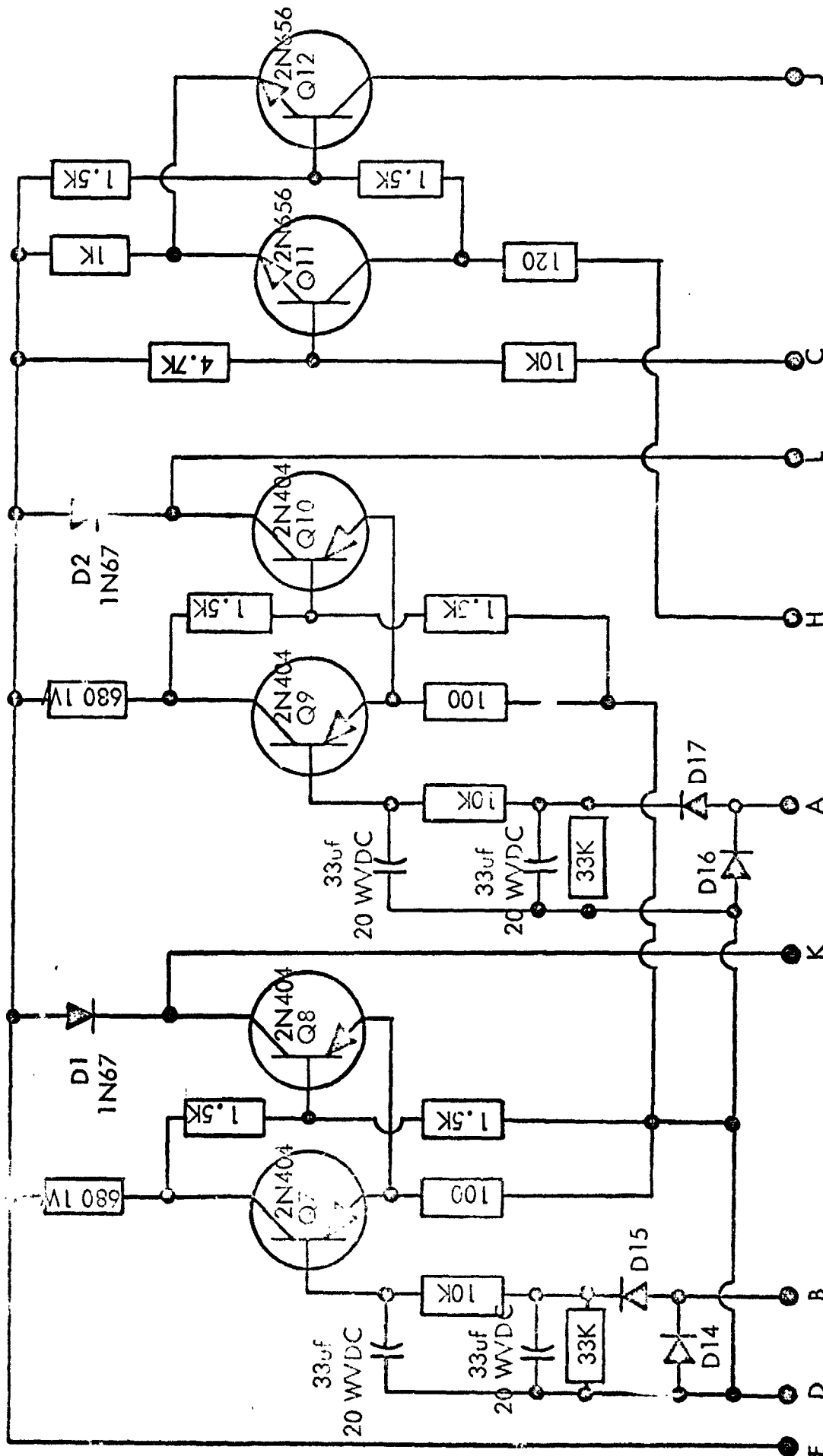
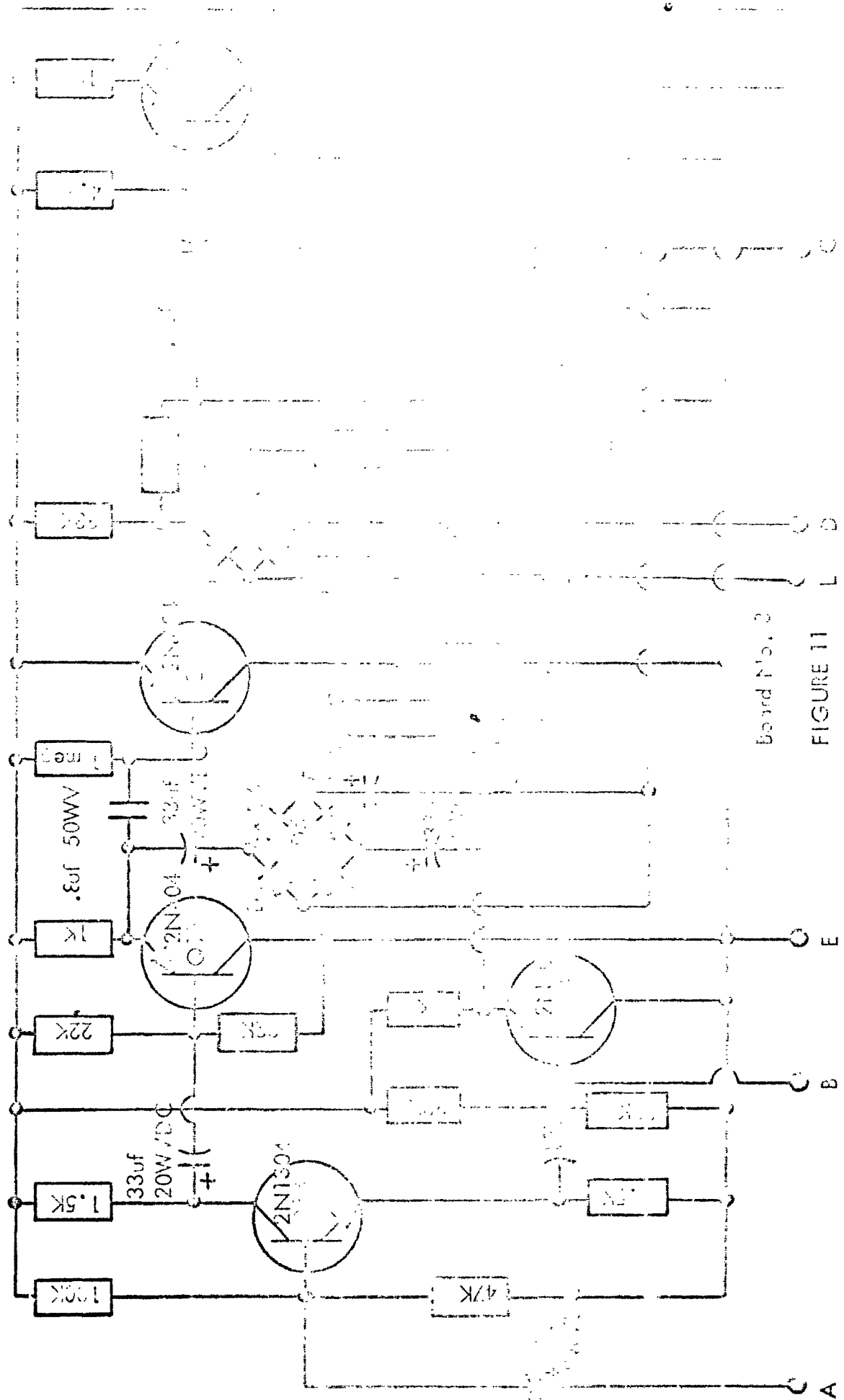


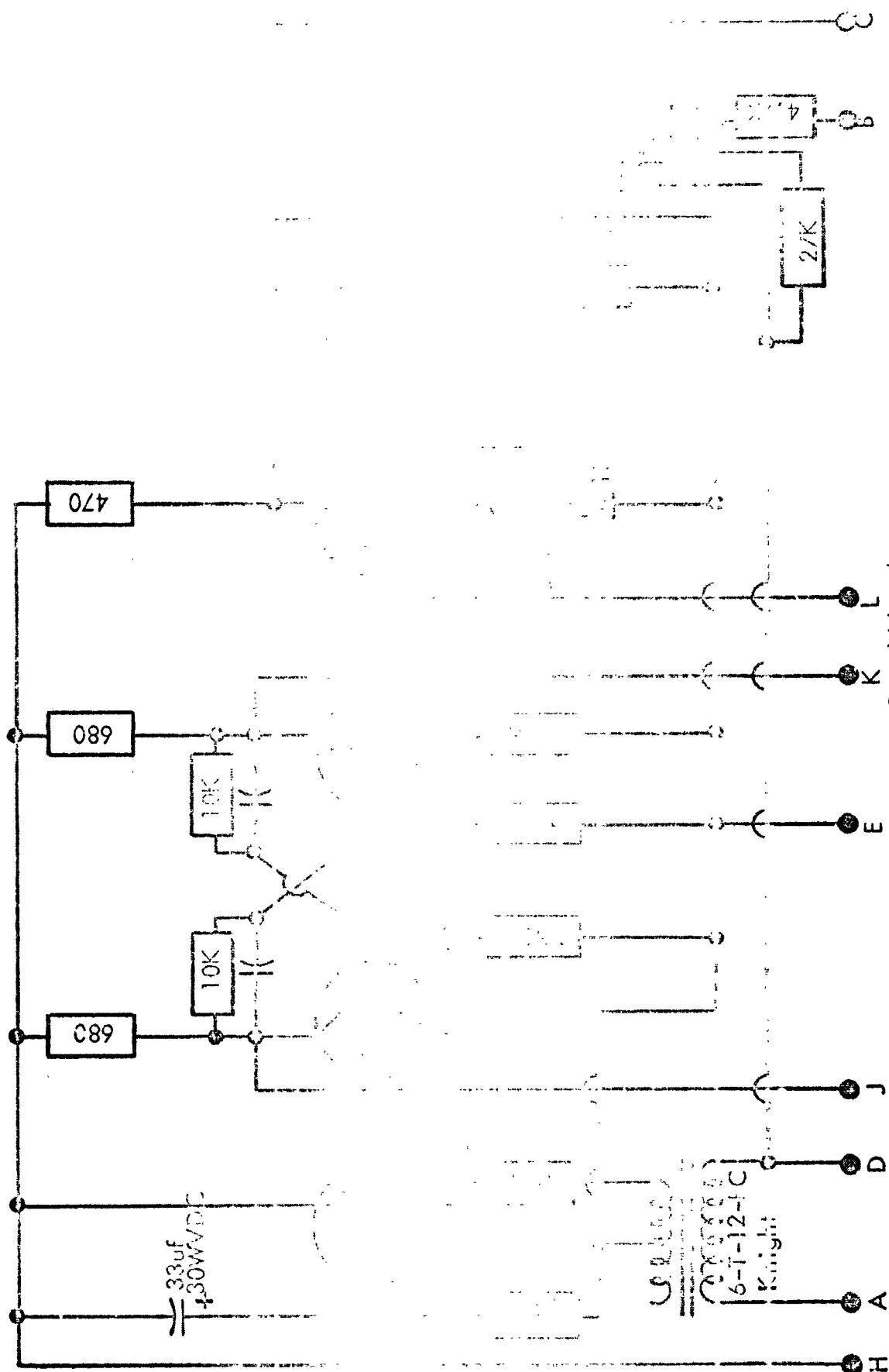
FIGURE 10

SCHMITT TRIGGERS



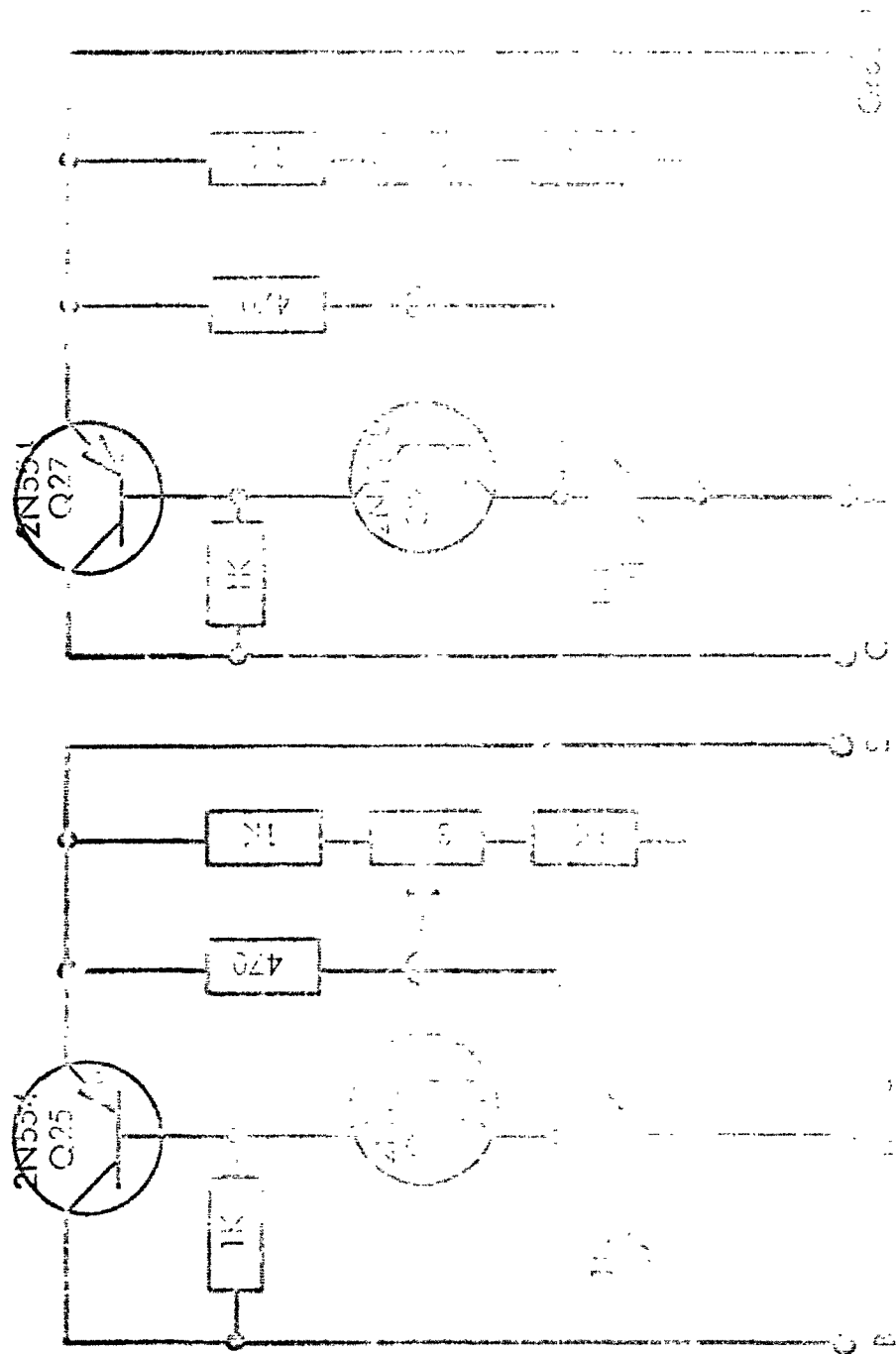
AUDIO OUTPUT ALGO PHASE SUB

FIGURE 11



Board No. 4
FIGURE 12

SWITCH DRIVER



Board No. 5
FIGURE 13

POWER SUPPLY REGULATORS

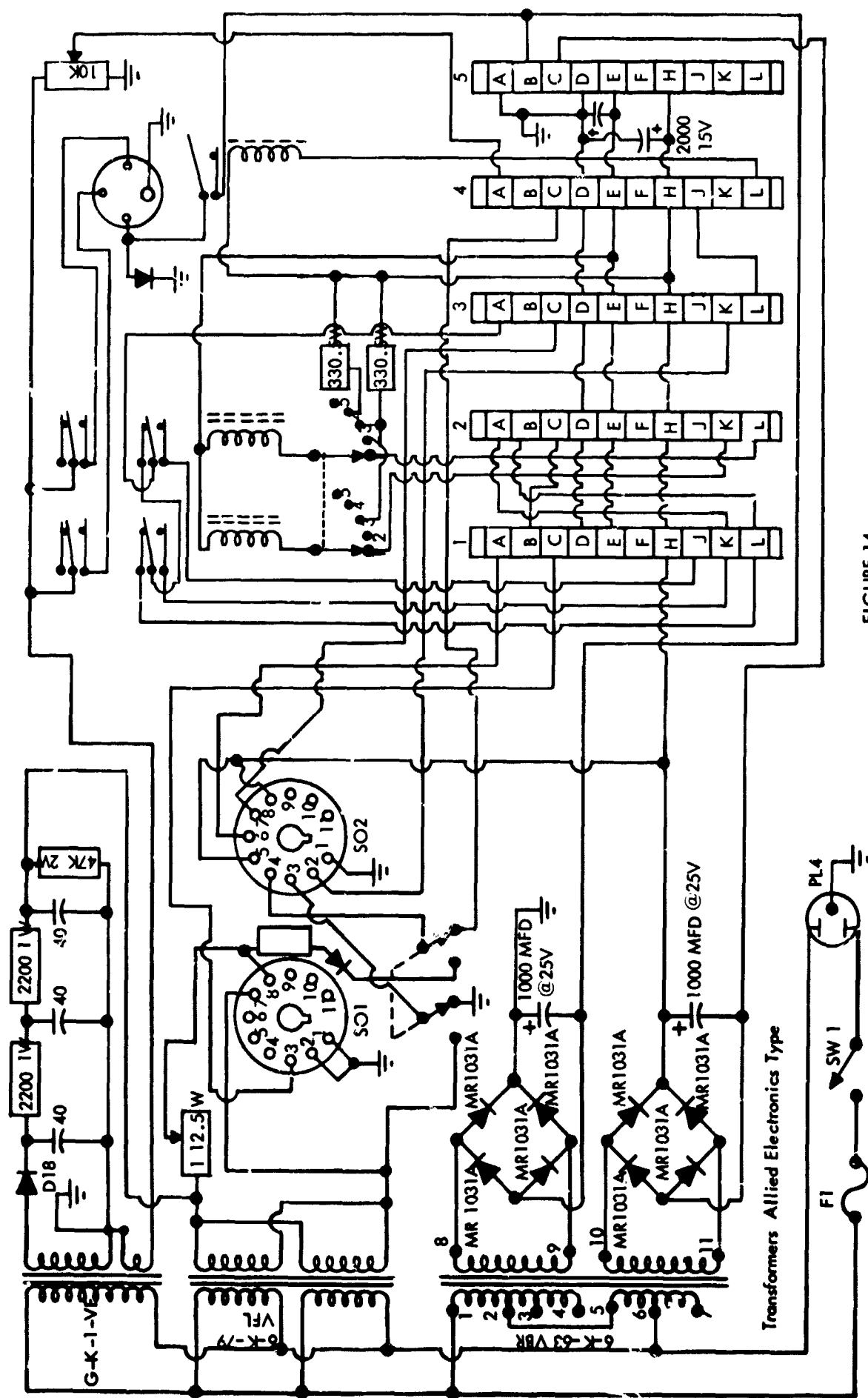


FIGURE 14

MAIN CHASSIS

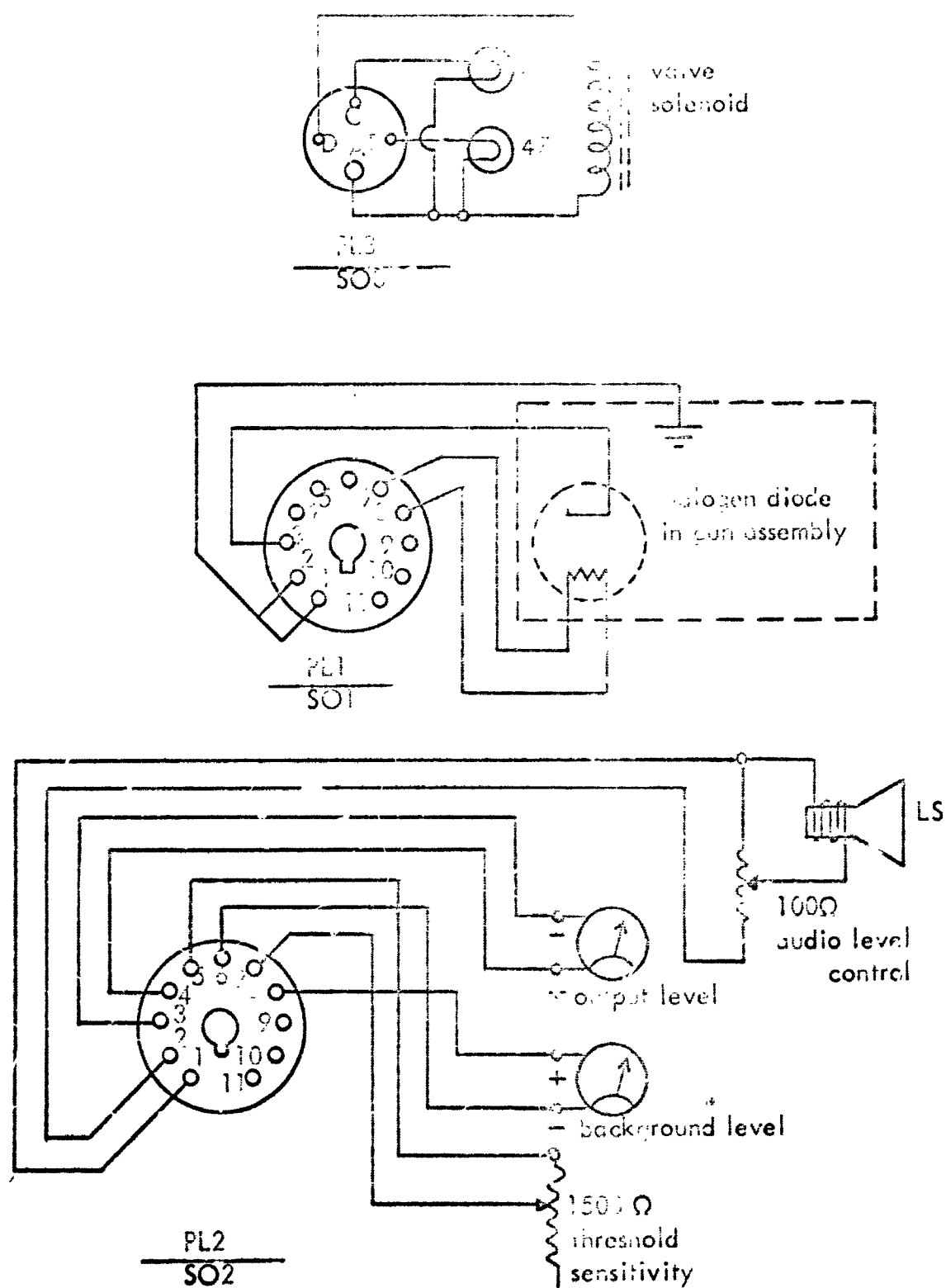


FIGURE 15
PLUG WIRING

The output of Q_1 is also fed through a capacitor (blocking the background component) to the four-stage amplifier, Q_3 Q_4 Q_5 Q_6 . These stages provide a gain of about 60 db for the gradient signal. The outputs of stages Q_5 and Q_6 are rectified and filtered in the blocks marked "LP Filt" to supply inputs to the two Schmitt triggers, Q_9 Q_{10} and Q_7 Q_8 . The purpose of these circuits is to provide range-switching action. They are set to trigger at levels below saturation of their respective amplifier stages. Thus, when the signal strength is high enough to be about to saturate Q_6 , its Schmitt circuit triggers and transfers the input of the power amplifier stage Q_{13} Q_{15} down to Q_5 . Before Q_5 saturates, its Schmitt circuit triggers and shifts the power amplifier input down one more stage to Q_3 . It will be noticed that these stages are so arranged that this switching results in no phase change.

The gradient signal is thus amplified through the appropriate number of stages, and after power amplification is rectified and filtered and applied to the gradient meter, M_2 . This rectified output is also used to control the frequency of the audio oscillator, Q_{17} , which is a unijunction relaxation circuit having a frequency which increases monotonically with applied voltage. This gives an audio signal on the speaker which increases in pitch with the magnitude of the gradient within each range of the instrument.

To give an indication of which probe is upstream in the gradient, a signal from the valve driver is combined with a pulse produced by a class-C stage in an "and-gate", the output of which is used to modify the sound of the audio oscillator. The valve drive consists of a flip-flop circuit synchronized to the line frequency by the unijunction count-down circuit. With this frequency

set for best valve switching rate, the air flow may be set by applying a known gradient direction, then adjusting the airflow rate so that the pulses are barely produced, resetting to cause them to move through a complete half-cycle, and then finally averaging these two pump settings.

(Note: If this feature is not considered worth the circuitry involved, it can be omitted without adverse effect on the remainder of the device.)

Operation of the Gradient Detector

The following comprises a manual of operating instructions delivered with the prototype detector.

For Automatic Ranging

Connect the Gradient Detector to a 110 V 60 cps source and turn on the power switch. Momentarily, depress the "heater check" switch and observe gradient meter while setting "heater adjust" rheostat (located on lower right side of front panel) to the "red line" which corresponds to approximately 10 V RMS across the diode heater. Observe this reading and maintain it during a warm-up period of ten minutes or more, or until it stabilizes. Set the function switch to its extreme counter-clockwise position, "automatic". (This control is located on the lower left side of the front panel.) Set the audio level control (top left control) to mid-range. Adjust audio threshold control (top right side of panel) just below the point where an audible raw-sounding note is heard. Proceed to sniff a freon sample from the G E calibrated leak standard set at a low leak rate (one-quarter ounce or less). The gradient meter should give an upscale reading. Simultaneously, the audio oscillator should break into an oscillation which should give a note that increases in pitch with a corresponding increase in

gradient level. At somewhere near a full-scale reading on the "gradient" meter, the automatic range switch should energize into its intermediate gain position, which is indicated by a light on the halogen gun assembly. It may be necessary to increase the leak rate on the standard leak to cause the automatic range selector to energize its low-sensitivity position, which is indicated by both lights burning on the halogen gun assembly.

Manual Operation

To hold the gradient detector in any one of the three gain ranges provided, turn the function switch one step toward the clockwise direction for "high" sensitivity which is indicated by no lights energized on the halogen gun. The next step clockwise will turn on one light to indicate that the "medium" sensitivity is selected. The next step will turn on both lights to indicate low sensitivity. The extreme clockwise position of the switch gives another "high" sensitivity range which is identical to the first "high" sensitivity position in operation. The unit is now ready to operate on any of the manual ranges or automatic range mode which the operator may choose in order to meet his specific leak detection problems.

High Background

Under high background conditions the halogen gradient detector has a built-in alarm to alert the operator that high background is present. This alarm is a solid state transducer ("Sonalert") which should give an audible output when the background meter reads about 3/4 scale. This alarm stays on until the background decreases to about 1/2 scale.

Circuit Differences Between the Model 1 and Model 2

The Halogen Gradient Detector, Model 2, has certain minor circuit differences which are due to the use of a different type of relay. These differences appear in the automatic range switching circuitry. These circuits are Schmitt triggers which are designed to operate a different type of relay than the Model 1. Therefore, it is necessary to change some of the resistance values to make the circuits compatible with Sigma 11F-1000-G/SIL relays. Only a (-9) volt supply is required for their operation, so that the emitter and base resistors are returned to ground. The Model 1 has these resistors returned to (+9) volts. The basic operation of the range switches remains unchanged.

The Schmitt trigger circuitry of the "Sonalert" driver in both models has been modified to use 2N656 transistors. The schematic diagram is unchanged with only the values of the input resistors modified to permit the high-background alarm to be actuated when a high-background condition exists.

CHAPTER VI

ACOUSTICAL METHODS

Late in the course of the investigation of state-of-the-art methods under NAS8-2563, a promising system of leak detection being studied by the American Gas Association came to light. This method consisted of injecting 400 cycle sound energy into the system being tested and then correlation-detecting the sound energy leaking through a break in the system. Obvious similarities and differences involved in the two problems of leak detection, in gas pipeline systems buried in supporting ground and in missile plumbing and tanks suggested that some experiments with open plumbing systems be undertaken. The compressed air system in the Engineering Building was chosen because of its ready availability and because its extent made it at least roughly analogous to systems of interest in missile testing. These experiments were inconclusive. Under proper conditions it was possible to detect sound coming from a no-pressure leak when the total injected energy was in the range of a few microwatts. However, results were not always repeatable, and lack of control over all parameters of the system made it impossible to decide just what the right conditions were. Other experiments with a controlled system were thus indicated.

Meanwhile, it was learned that Mine Safety Appliances of Pittsburgh, Pa., had been selected to develop the American Gas Association's leak detection apparatus. The engineering department of MSA was contacted and conversations arranged and held. On the basis of these talks and the reported field tests of partially developed MSA apparatus, an investigation was outlined and initiated.

From the reported experiences of MSA and from information obtained from tests of the Delcon Ultrasonic Translator here and at NASA in Huntsville, several types of difficulty were predictable. One of these was due to the fact that the plumbing systems so far tested for sonic injection had been found to radiate energy from discontinuities in the system other than leaks. Thus a "leak" located by simple correlation detection methods might prove to be a weld or some flaw in the pipe or even a tee or other fitting. Secondly, the method was reported to require injection of very high energies if system pressure was above a few psig. Further, with the Delcon Translator, echoes were very troublesome.

The false leak indications to be expected from the simple sound injection system led to the consideration of ways and means of obviating this difficulty. One possibility is the use of a combination of active and passive acoustical techniques, i.e. to attempt to modulate the leak rate by injected pressure changes, either sinusoidal or pulsed, and to sense and demodulate the ultrasonic noise produced by the leak itself. Since the air escaping from a small leak does so in a random statistical way, the process is accompanied by a certain amount of noise. Experiments have shown that this noise has a spectrum mainly concentrated in the neighborhood of 40 kcps. Some measurements were made to determine if the amplitude of this noise was sensitive to variation of pressure in the system. This proved to be the case and a simple AM demodulator was shown to be able to recover the pressure variation waveform from the noise. However, lack of sensitivity of the available transducer in the frequency range of interest limited promise of immediate utility of this method, and work was tabled to

allow more effort to be devoted to activities considered of more current importance.

Data on the variation of sound output as a function of angle about the leak axis, and data on variation of sound output with pressure have been obtained and are shown in Figure 16, 17, 18 and 19.

Status of this work at the end of the time covered by this report is that no definite conclusions can be drawn on the basis of available data. It is believed that if more sensitive transducers in the 30 to 50 kcps range can be developed, an extremely practical method could result.

Developments on the transistor microphone and some similar semiconductor transducers are being followed as closely as industrial security measures permit. Early models of this device were reported to have good sensitivities well beyond the required range, but nothing has yet appeared on the market. Further development here would seem to await a breakthrough in the transducer field.

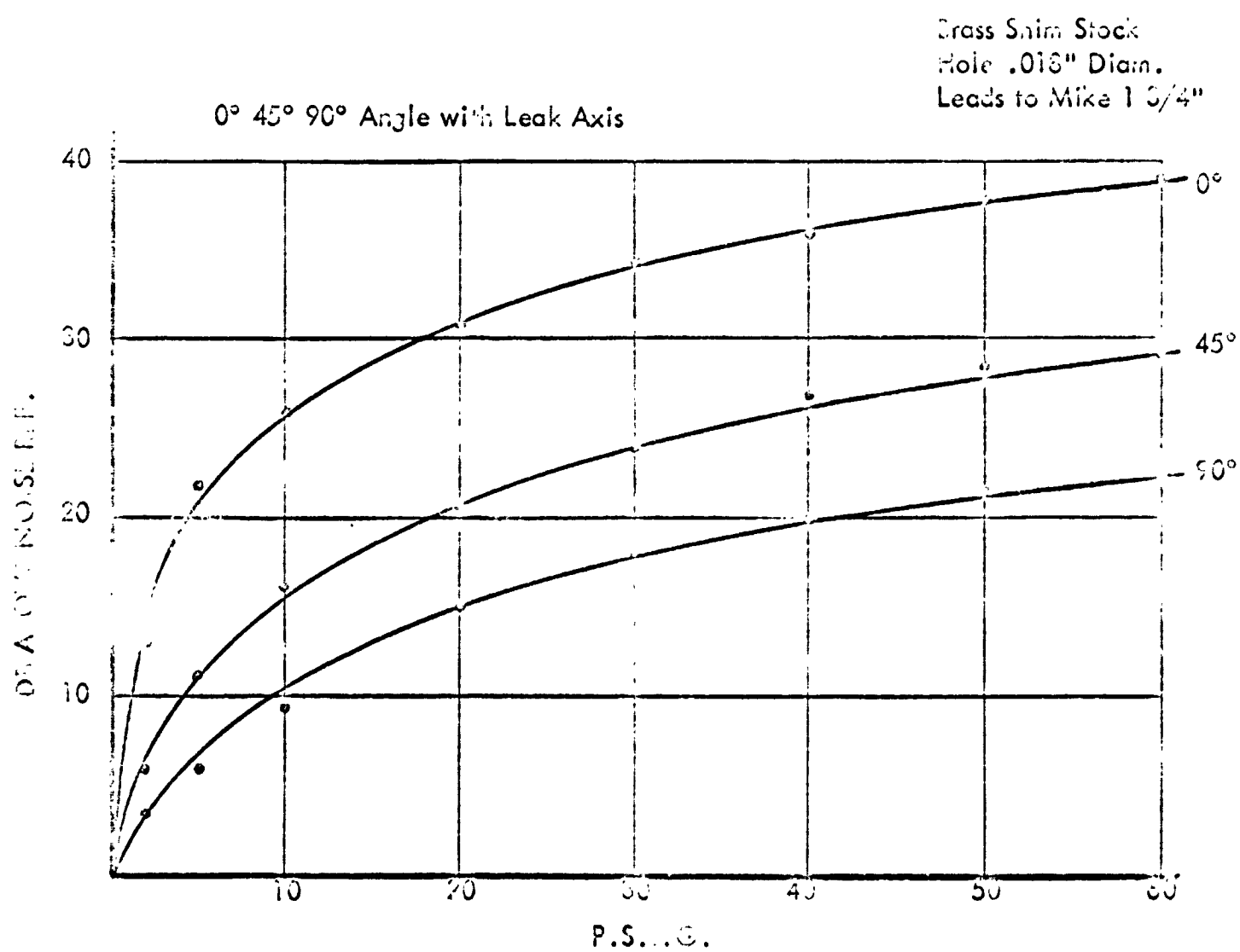


FIGURE 16

LEAK NOISE VS. PRESSURE

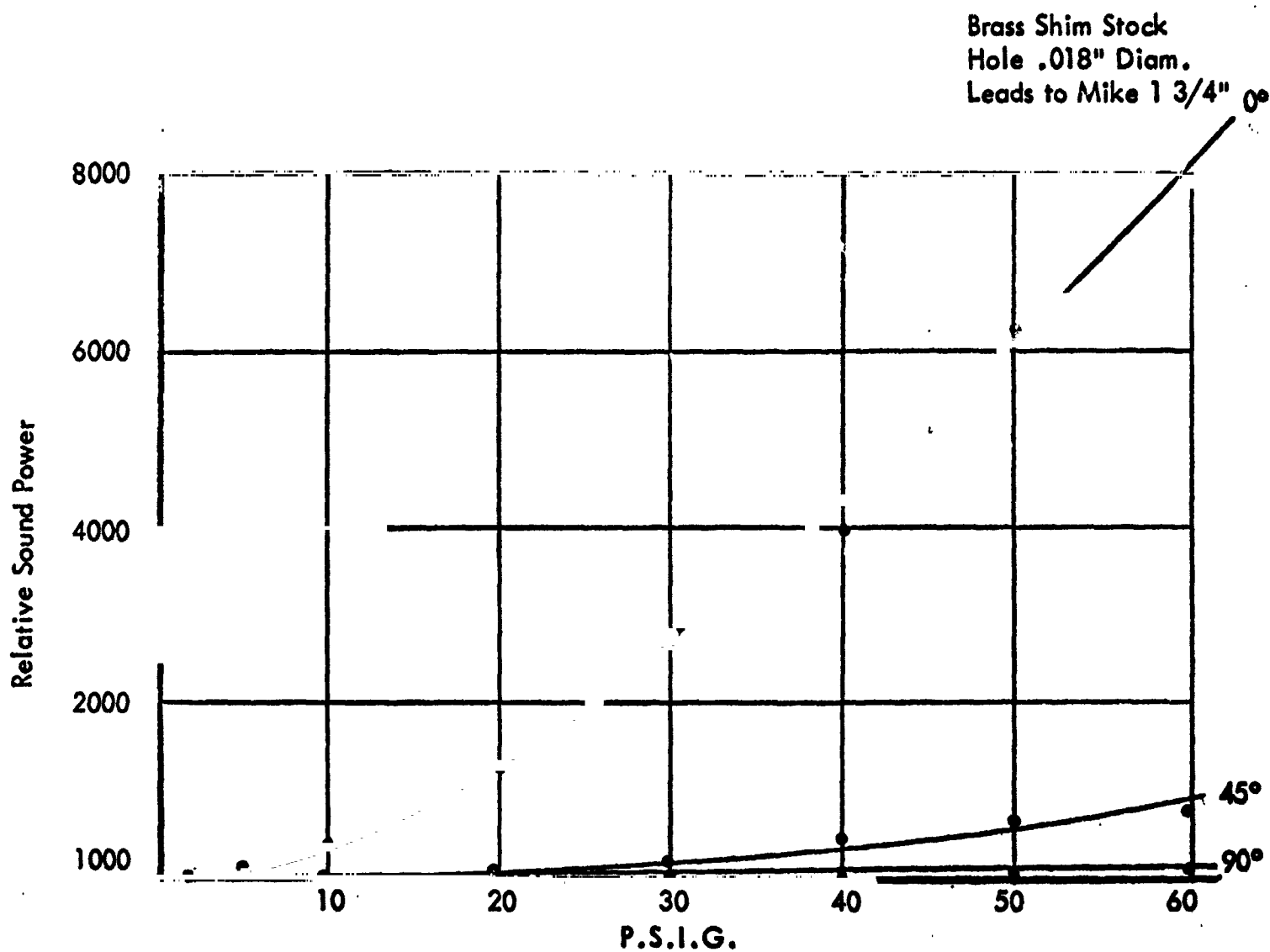


FIGURE 17

LEAK NOISE VS. PRESSURE

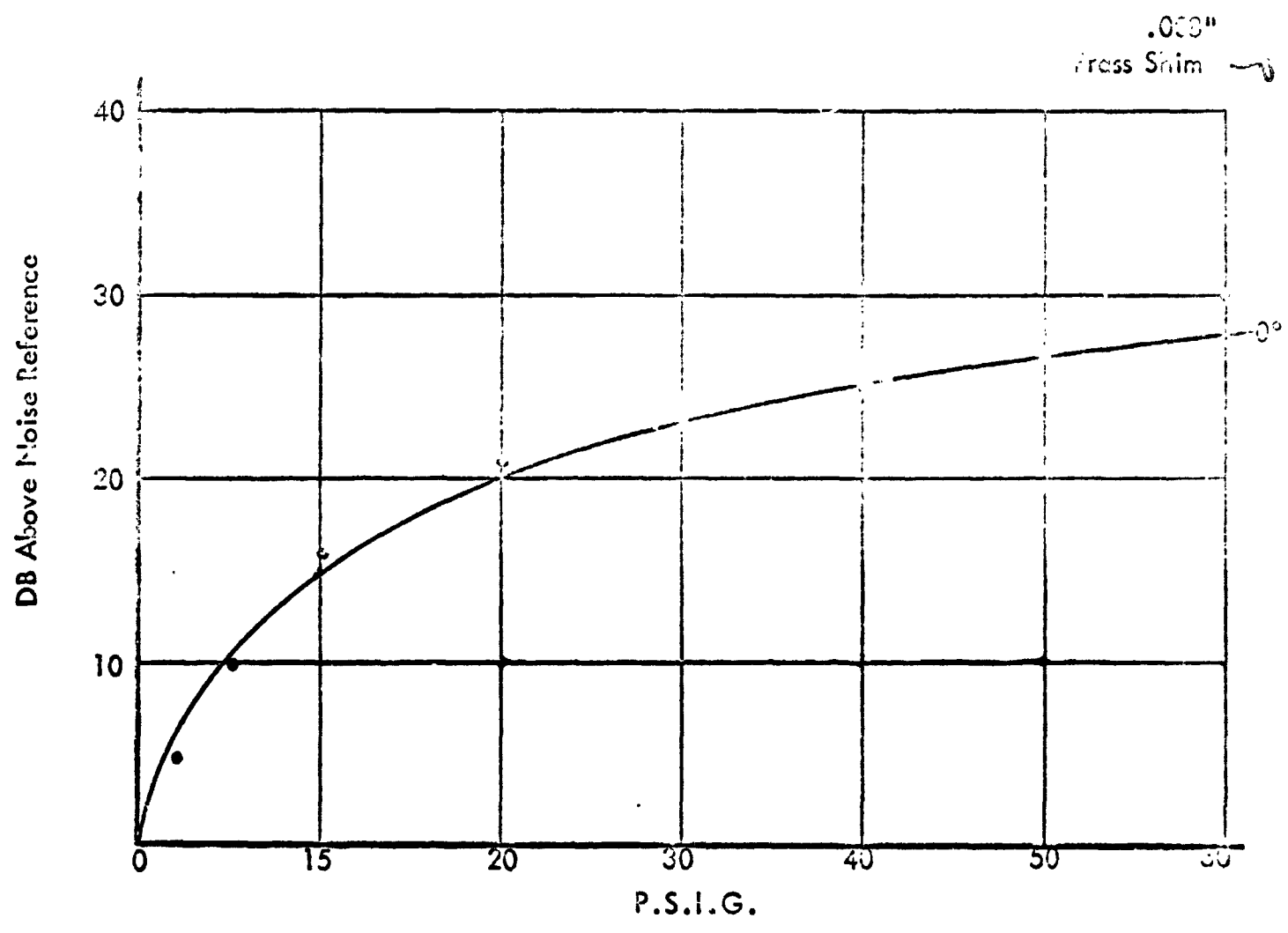


FIGURE 18
LEAK NOISE VS. PRESSURE

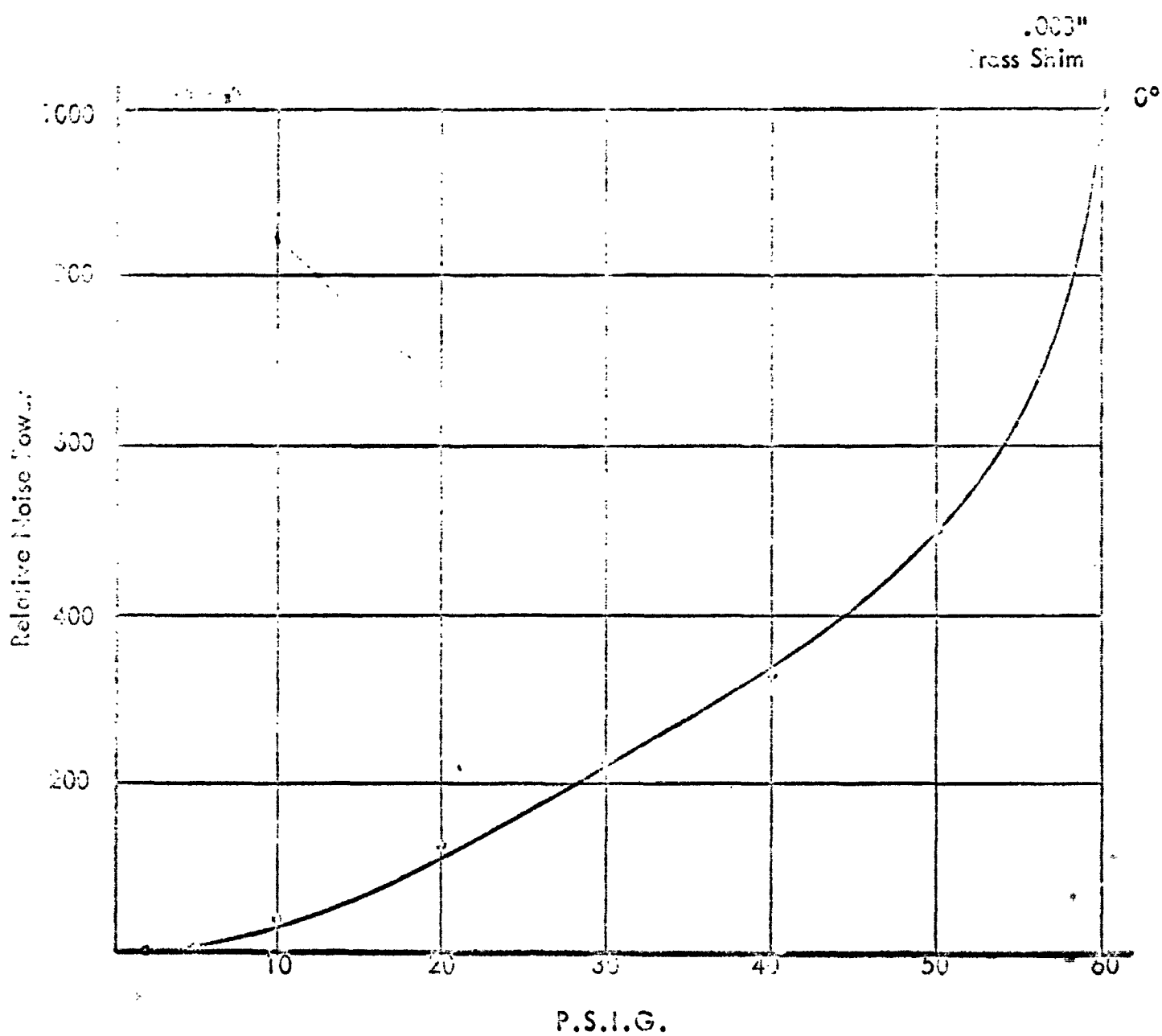


FIGURE 19

LEAK NOISE VS. PRESSURE

CHAPTER VII

HALOGEN DIODE IMPROVEMENT STUDIES

The fact that the hot anode platinum diode of the General Electric standard halogen gun or of the Ohio University time sharing gradient sensing modification requires 30 watts heating power and an air pump, places an awkward limitation on the miniaturization of these devices. During the latter part of the past twelve months a theoretical study of methods for removing these limitations has been pressed.

It is a relatively simple matter to miniaturize the electronics of the halogen detector by simply using transistors instead of vacuum tubes and tantalytic miniature capacitors where applicable. Indeed, this is the circuitry used in the Ohio University Time Sharing gun. There remain, however, the diode heater transformer and the air pump. A comparison of the pounds required per hour of operation for various possible energy sources is given in Figure 20. It is obvious from this data that the use of propane as a source of thermal energy will permit the removal of the heater transformer without requiring the substitution of a prohibitively heavy chemical battery. If the propane can also supply the energy for pumping the sample, the device can be further lightened and freed from the restrictive and inconvenient power cord.

A design for a device which combines the function of anode heater with that of air jet pump in one compact package is shown in Figures 21, 22, 23, 24, 25, 26, and 27. The basic geometry of the platinum diode (concentric cylinders with the inner cylinder serving as anode) has been preserved since the anode directed gradient of the electric field strength is required to bring the polar freon molecules into contact with the hot surface for contact ionization. Further, with

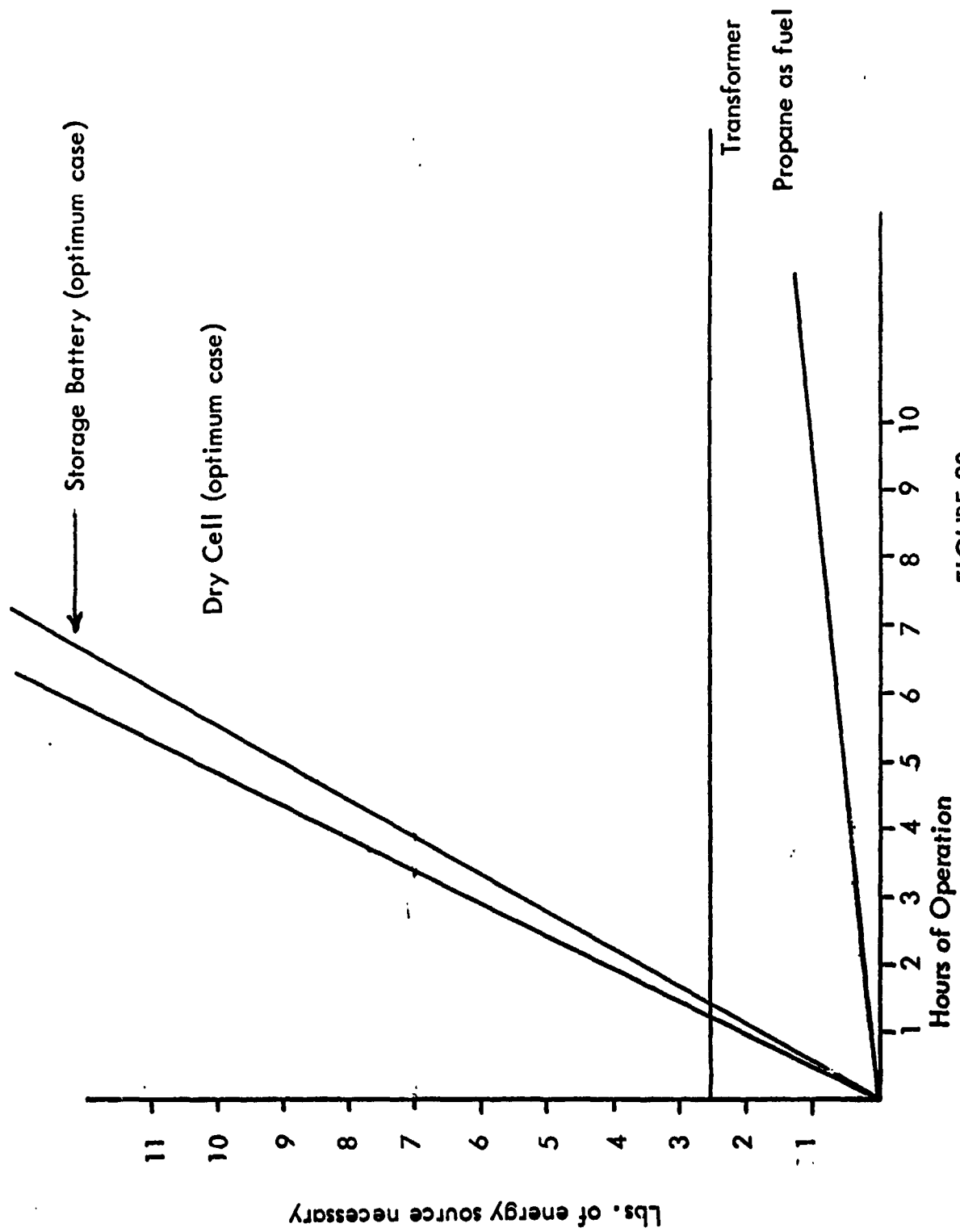


FIGURE 20

POUNDS OF ENERGY SOURCE VS. HOURS OF OPERATION

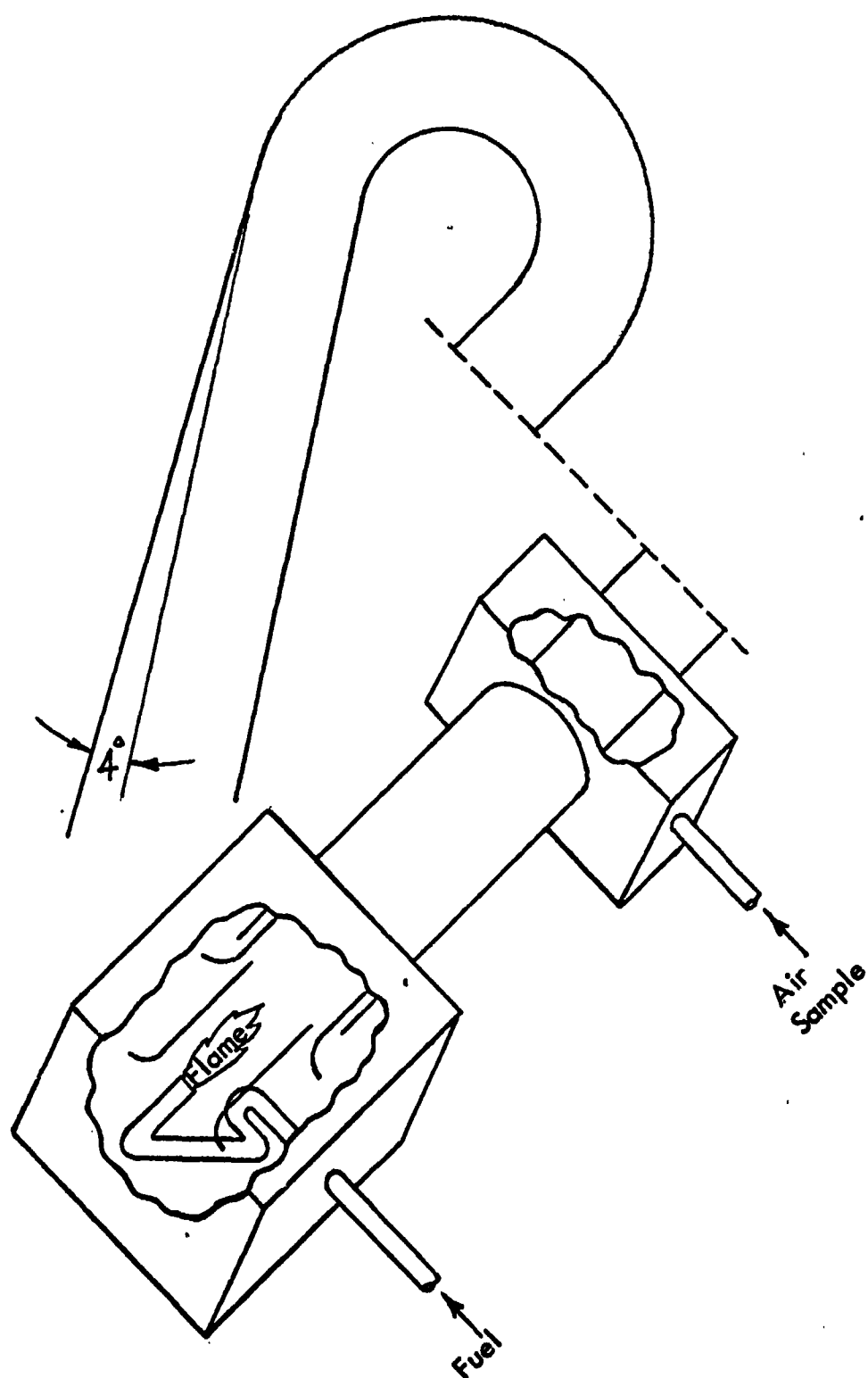


FIGURE 21

DESIGN FOR COMPACT HALOGEN GUN HEAD

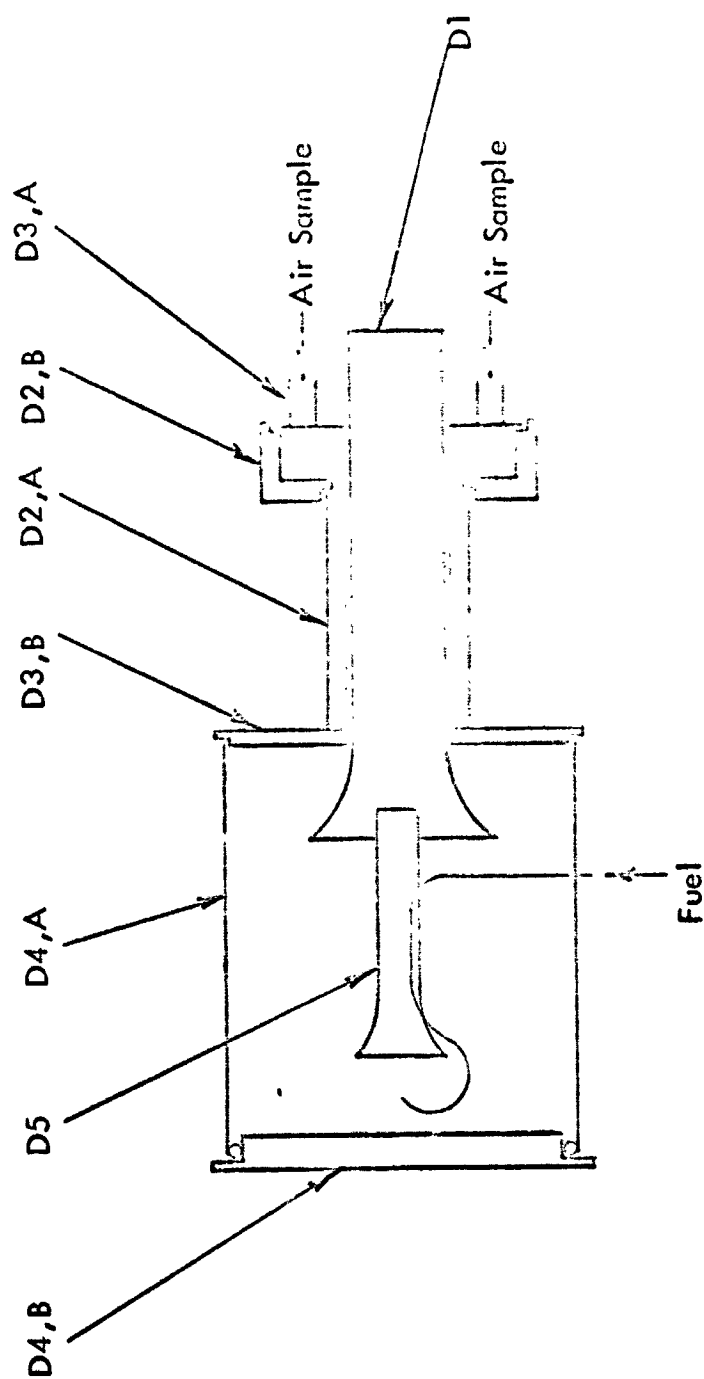


FIGURE 22

PLAN OF HALOGEN GUN HEAD

D1

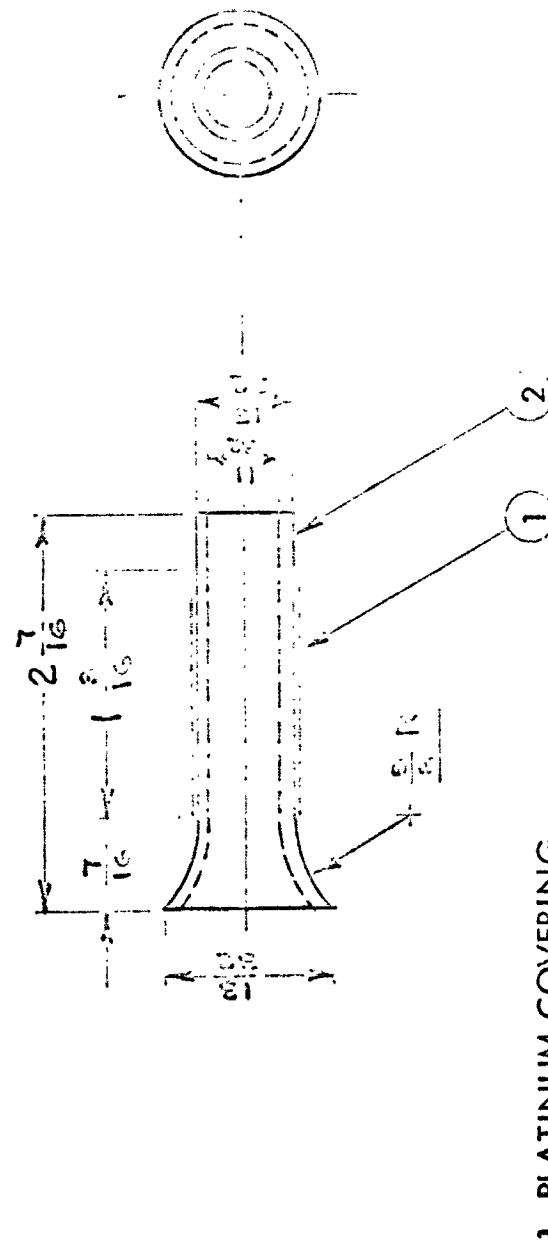


FIGURE 23

DETAIL FOR D1 COMPONENT

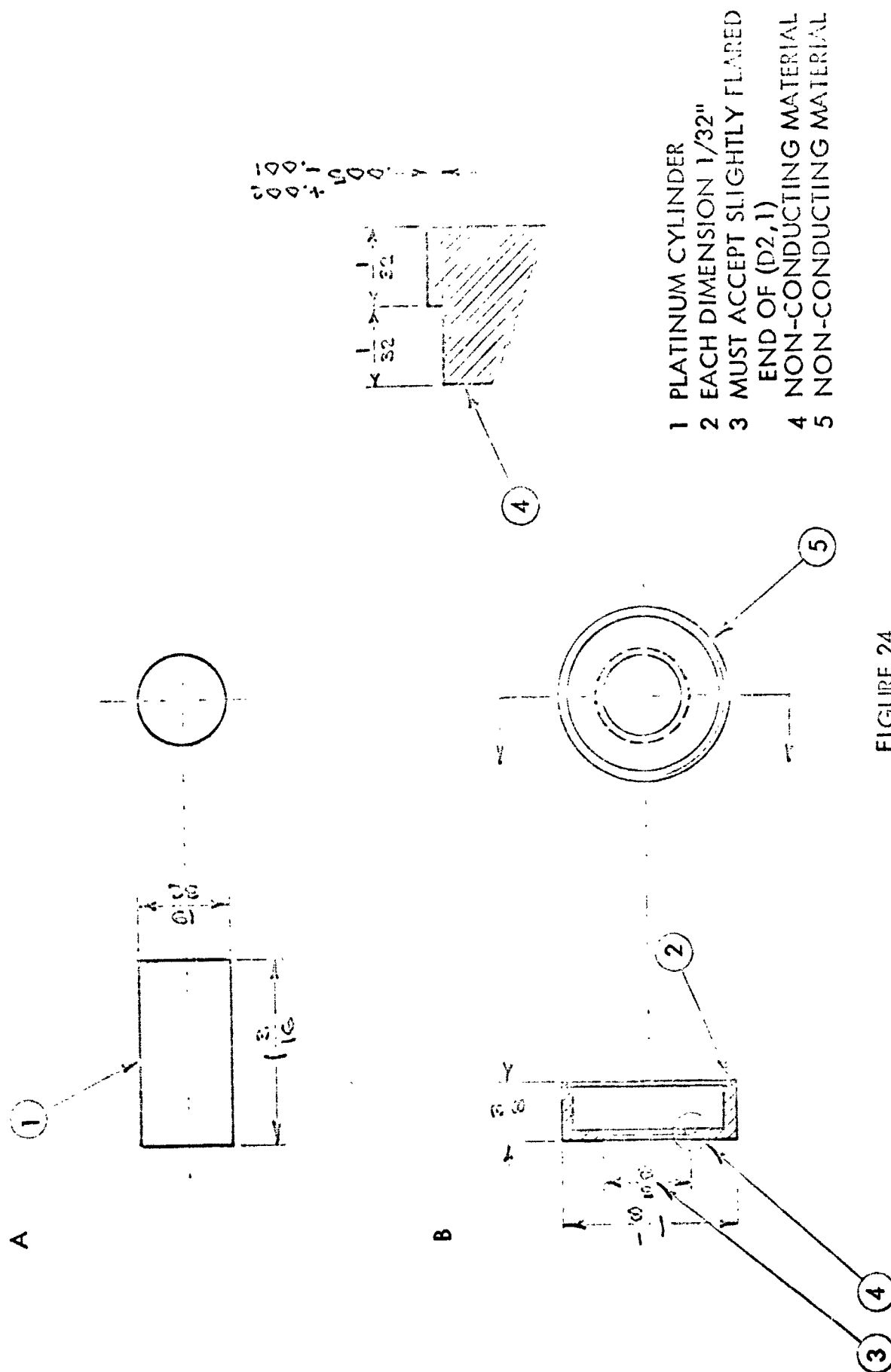


FIGURE 24
DETAILS FOR D2 COMPONENTS

D3

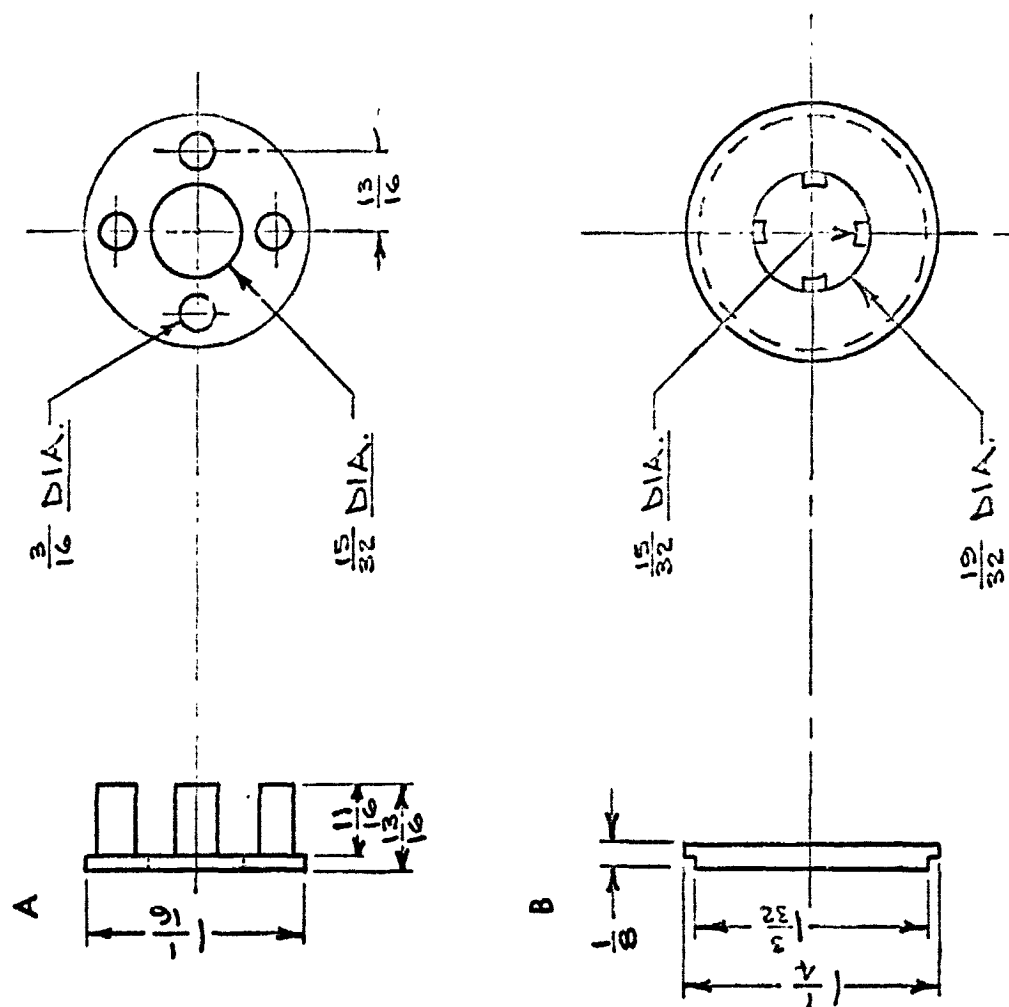


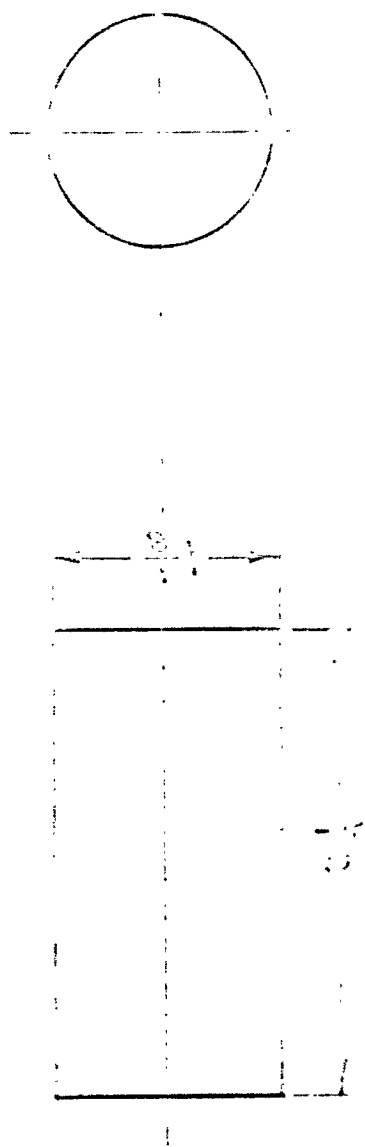
FIGURE 25

DETAILS FOR D3 COMPONENTS

D4

37

A



B

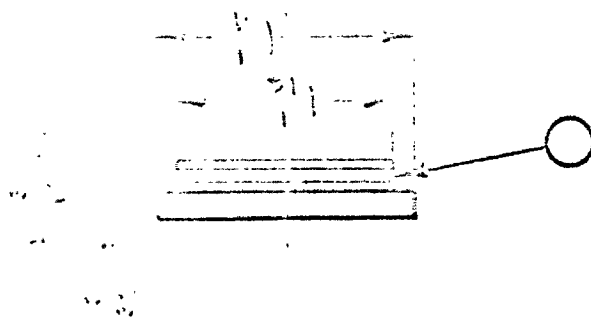


FIGURE 26

DETAILS FOR D4 COMPONENTS

O-Ring Groove

D5

70

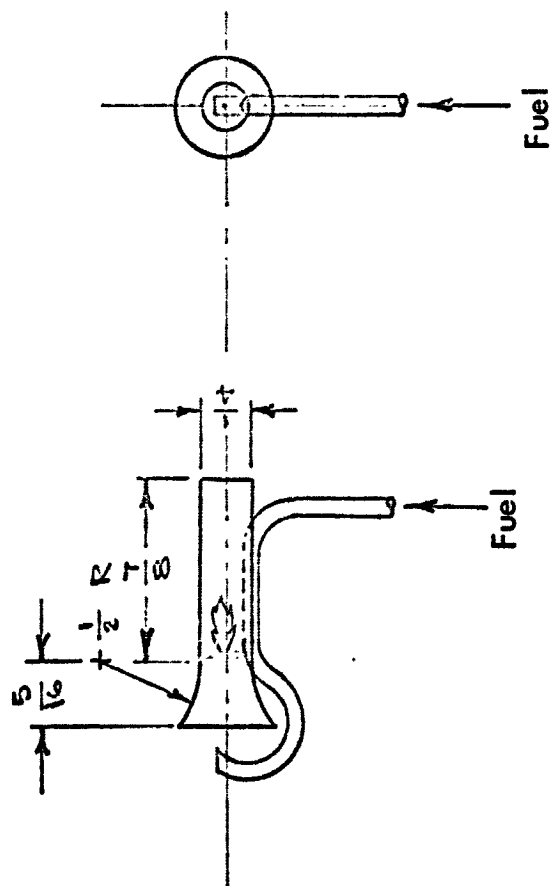


FIGURE 27
DETAILS FOR D5 COMPONENTS

this design the cathode furnishes heat shielding and thus economization of the heat power. The choice of the almost toroidal shape for the remainder of the device is dictated by the necessity for avoiding chimney effects which would make it mandatory always to hold the gun in the same position.

The fuel is preheated by bringing it to the nozzle through a section of tube passing close to the high temperature zone in order to enhance the jet pumping action.

At present plans are being drawn preparatory to building a prototype model to test the thermodynamic and aerodynamic actions. As soon as this is available, tests will be run and modifications made where necessary.

The theoretical and practical work which have resulted in this design are being published as a masters thesis which will become part of the records of this contract and will be available for use as required.

CHAPTER VIII

VIBRATING CAPACITOR STUDIES

As pointed out in the Second Formal Report*, the vibrating capacitor shows some promise as a transducer for the detection of polar molecules in a gas-air mixture. This device has been used for some years as a converter for producing an ac signal proportional to an applied dc signal for the purpose of amplifying minute dc signals with drift-free ac amplifiers. This is possible because of the periodic variation in the elastance (reciprocal capacitance) of the device. Either the voltage, or the charge, or both must change with the change in elastance. Thus, if the capacitor is connected in series with a dc source and a resistor, and its plates driven periodically with respect to each other, a periodic voltage will appear across the resistor as well as across the capacitor.

The function of the capacitor in leak detection is twofold: (1) to detect differences in gas air mixture composition, and (2), to pump the air samples into the test chamber.

The elastance (reciprocal capacitance) can be expressed as $S = kd/eA$ where d is the separation of the plates; A the (effective) area of a plate, k a constant depending on the system of units; and e the dielectric constant of the air mixture between the plates. It can be seen that the change in elastance and therefore the voltage produced by this change depends upon both d and e . By maintaining a steady vibration, for example,

$$d = d_0 + d_1 \cos \omega t$$

the voltage can be made to vary with e , which is a function of the composition of the air gas mixture between the plates.

* Second Formal Report - page 149

In application, it is planned to use a three-plate capacitor such as that indicated in Figure 28 in a bridge circuit. Each section of the capacitor will draw air through its own probe causing an unbalance of the bridge when there is a gradient of ϵ . It is expected that a detectable unbalance will result from gradients normally encountered in leak detection work.

The second function of the capacitor is to act as an air pump for bringing in the samples. By furnishing each section with a pair of valves, it is expected that the positive displacement pump thus created will be sufficiently efficient to bring in samples at the desired rate.

Work thus far has been limited to making some measurements on a single section vibrating capacitor inherited from a previous university-supported research project. Initial data has confirmed the presence of the expected fundamental frequency output voltage and current. Order of magnitude calculations have shown that the signals expected from change of dielectric constant would be lost in the noise of the presently available equipment. Current efforts are therefore directed toward setting up refined equipment and to more effective shielding for elimination of unwanted noise. Work will also be undertaken to test the pumping action of the capacitor.

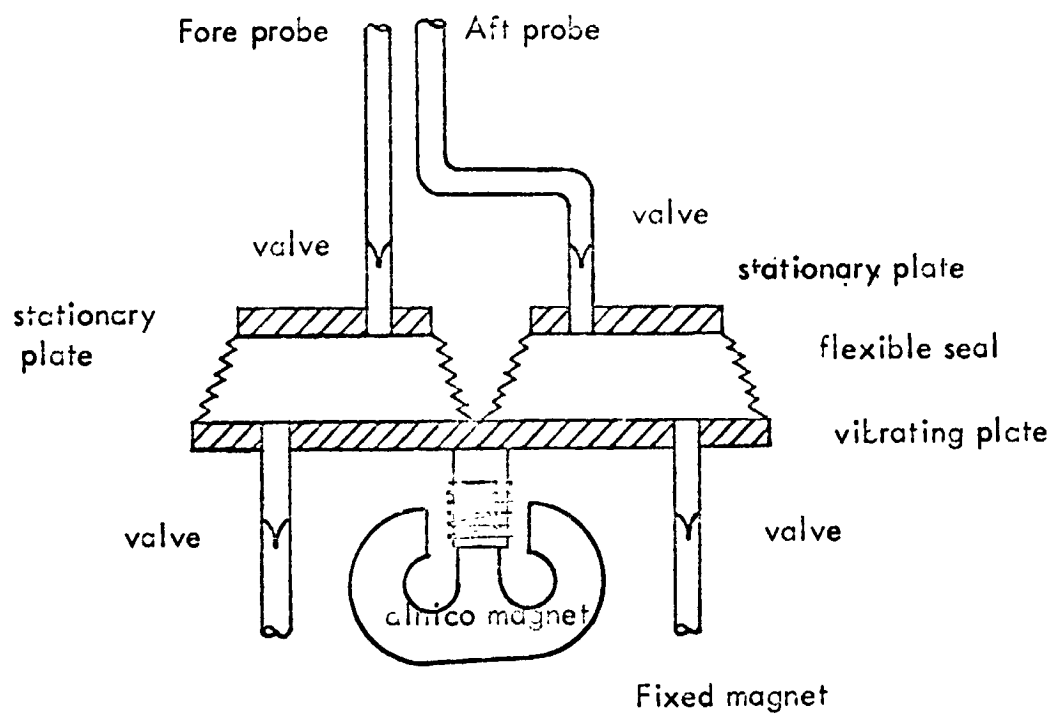


FIGURE 28

VIBRATING CAPACITOR BRIDGE ELEMENT (artist's conception)

CHAPTER IX

AMERICIUM 241 STUDY

During the course of the continuing state-of-the-art investigation, attention was called to a device used as a fire alarm, which seemed to offer promise in regard to leak detection. This device, known as the Pyr-A-Larm*, operates on a quite simple and effective principle. Two ionization chambers, one open to the air of the room and the other closed, are connected as a voltage divider to supply voltage to the starter element of a cold cathode gas relay tube of special design. Under normal conditions, with ordinary air in both the open and closed chambers, the voltage on the starter is below triggering level. When smoke or vapors enter the open chamber, its ionization current is caused to decrease, causing its apparent resistance to rise and with it the voltage on the starter electrode of the relay tube setting off the alarm. The source of ionization for each chamber is a minute quantity of the artificial radioactive isotope Americium 241. The quantity of material used, 80 microcuries, has been described** as "one tenth that of the average luminous wristwatch dial".

* manufactured by Cerberus Gmbh of Bad Ragaz, Switzerland and distributed in this country by Pyrotronics division of Baker Industries, Newark, N. J.

** "A wristwatch with a luminous dial produces radioactive radiation of an average magnitude greater than 10 times the radiation produced by these detectors, and the maximum radiation dose that could possibly be received from these detectors is considerably below the allowable amount for unrestricted areas under United States Atomic Energy Commission Title 10 Code of Federal Regulations - Part 20.105" (U. S. Radium Company, Morristown, N. J.)

One of the most attractive features of the scheme results from the long half-life of Americium 241. This half-life of 470 years guarantees that the source of ionizing power will not only be portable and independent of power cords, but will never have to be replaced by the original owner.

The problem with which this project is concerned is the sensitivity of such a detector to usable tracer gases, especially, but not solely, freon. In order to test this, two Pyr-A-Larm sensing units were borrowed from the distributor. These proved to be insensitive to reasonable concentrations of freon in their normal mode of operation. This insensitivity did not, however, preclude the possibility that there might be some other mode of operation which would be sensitive, since the change in starter voltage of the alarm system (normal mode) had to be sufficiently large to prevent accidental alarms by noise voltages. Further experiments were indicated.

In order to obtain quantitative information as to the behavior of the ionization chambers in the presence of freon-air mixtures, a series of experiments was performed. Figure 29 shows the essential features of the apparatus used. The Americium sample, Am, is mounted on a threaded member so that it may be accurately positioned along the chamber axis external to the chamber itself. The chamber, Ch, has two electrodes, a copper screen facing the source which permits the 5.5mev alpha particles (the main energy carriers from the Americium source) to enter freely, and a solid copper electrode, B, to complete the diode. The body of the chamber is machined from plastic to minimize leakage currents. A small motor driven fan was included and chamber, source, and fan were placed under a bell jar to allow control of freon concentration. As described in Chapter IV of

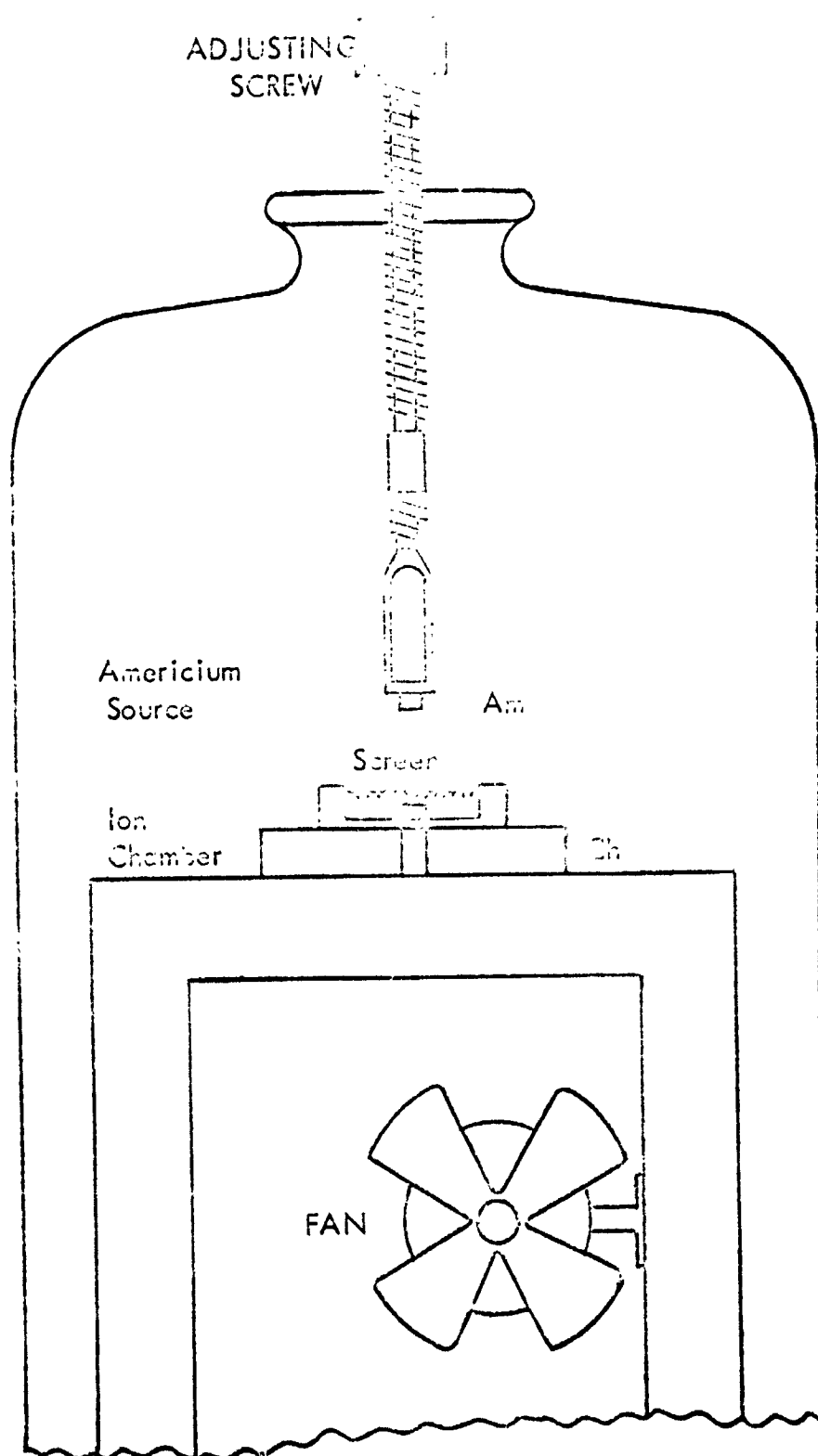


FIGURE 29

DETAIL OF BELL JAR TEST CELL

this report, various concentrations of freon in air were set up under the bell jar, and volt-nanoampere characteristics of the chamber measured with sample position (as distance from screen end of the chamber) as a parameter. Figure 30 shows current as a function of freon concentration with source position as a parameter. These curves were made with an accelerating potential of 270 volts. Figure 31 shows the effect of changing this voltage. Here current in picoamperes is plotted against voltage with source position as a parameter. The mixture is 1% freon by volume.

Figure 30 indicates that, for closest source position and with 270 volts across the chamber, the rate of change of current with freon concentration is initially 40 picoamperes per percent change. On this basis, the difference in current caused by a change in the freon concentration of 1 ppm would be in the neighborhood of 4×10^{-15} amperes, a rather difficult current to measure in the face of ordinary noise. Since this estimate is based on the obviously unsupported assumption of linearity over the range of 0% to 1% freon, more data is presently being sought to detail this significant range of the curves.

Two other lines of investigation are being followed. Both of these are aimed at amplifying the freon concentration in such a way that measurable changes in current may be obtained.

The first of these approaches is suggested by another device discovered in the course of the state-of-the-art search. This device is a noxious gas detector called the Billionaire* which uses chemical conversion to obtain large particles

* manufactured by Mine Safety Appliances, Pittsburgh, Pa.

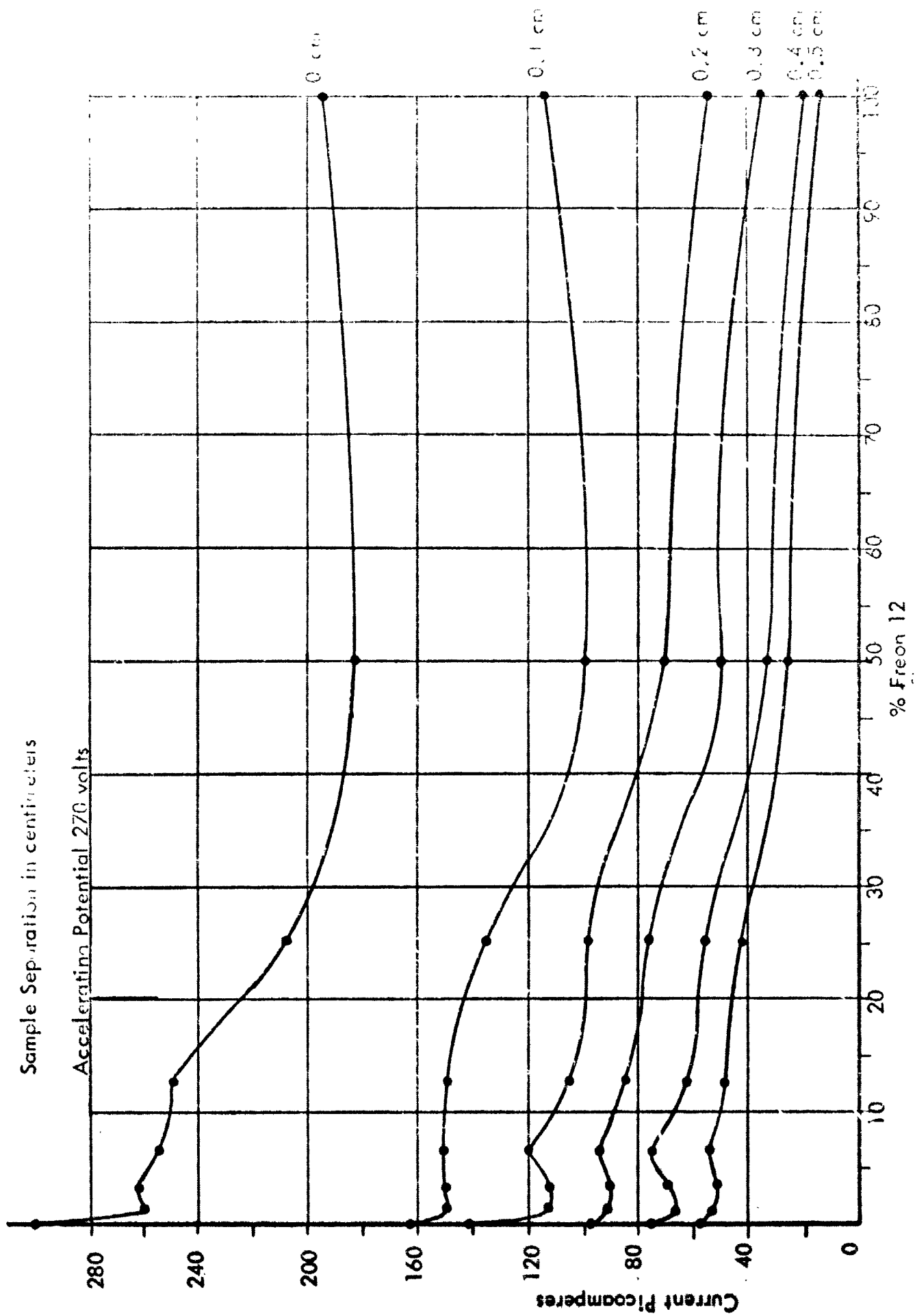


FIGURE 30
CURRENT VS. FREON CONCENTRATION

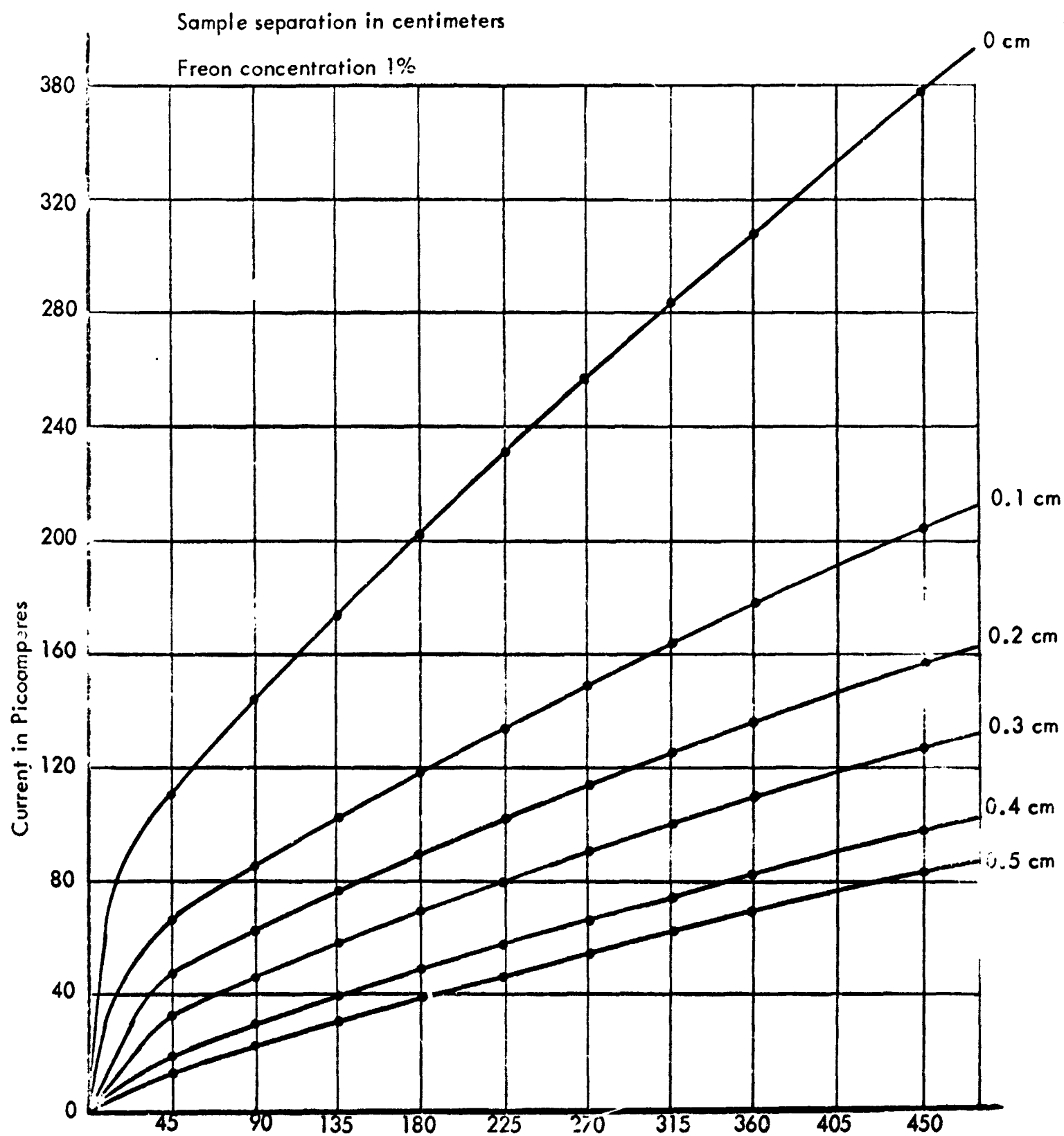


FIGURE 31

CURRENT VS. CHAMBER VOLTAGE

from the molecules of gas to be detected. For example, HCl (hydrogen chloride) can be made into an optimum vapor by passing it over certain amines. Freon will react with hot copper oxide forming, among other things, copper chloride which forms detectable groupings of molecules. The sensitivity of the device thus employed is reported to be too low to make it competitive with the ordinary halogen detector. This line of investigation, then, must seek a better chemical conversion process than pyrolysis with copper oxide.

The second approach is suggested by the action attributed to the platinum diode of the GE halogen detector which uses a field intensity gradient to move the polarized freon molecules to the hot anode for ionization by contact. If this process can be used to concentrate the freon as it is ingested and the detector geometry can be so arranged that the chamber sees only this concentrated portion of the sample, then current differences may not be too small to detect conveniently.

Both of these approaches are being studied.

CHAPTER X

PRESENT STATUS AND PROJECTED WORK

The Task described in Chapter IV of this report provides a logical continuation of the work done on the Ohio University Time Sharing Halogen Gradient Instrument. This task, the subject of Chapter V of this report, has been temporarily halted while working models of the detector are being built and are as yet unavailable for testing. In order to have available a means of establishing complete quantitative performance figures for the instruments when they become available, this task will have a high priority.

Concurrent with the development of the testing facility, work will proceed on the miniaturization of the sensitive element of the halogen gun as described in Chapter VII of this report. This will require fabrication of a unit and tests of the working principle of the jet air pump combined with the propane thermal unit. As testing progresses and modifications are tried, further evaluations of the idea will be made.

Theoretical studies of further possibilities for optimization of the hot anode platinum diode halogen detector are in progress and will be continued. Present studies of the probable mechanism of this diode suggest that a closer look at the action of the fields within the diode may point to other geometries for both the aerodynamic and electrostatic functions. There seems to be a possibility that these functions might profitably be at least partially separated with enhancement of the efficiencies of both. The initial effort in this direction will be to apply the techniques of electron optics to polar molecules, using field strength gradients as

the force fields of the process. If a gradient of halogen concentration within the sample can thus be achieved, aerodynamic redesign of the rest of the geometry will seek to channel the mixture so as to bring only the concentrated portion over the active part of the transducer. These ideas should have passed beyond the "brainstorming" stage within a few weeks.

Other methods of producing ionization of the freon selectively in air will be actively sought, studied, and evaluated with respect to their suitability as replacements for the present hot platinum anode.

Refinement of the vibrating capacitor mentioned in Chapter VIII of this report is in the hands of the shop, and when the improved equipment is finished tests will be run and the data so collected will be analyzed.

The development of acoustical methods outlined in Chapter VI awaits improvement of the transducer. The state-of-the-art survey (Chapter III) will be alert for any breakthrough which may offer a solution to this problem.

Improved data on the action of Americium as proposed in Chapter IX will be sought. This is mainly a matter of extending the range of voltages considered, and of filling in details missing from the original broad survey treatment of the process. Work in this part of the project will be considerably facilitated by the continuing development of the general testing facility described in Chapter IV. There is also good prospect of finding application here of the results of the theoretical studies of detector element geometries outlined above.

The literature search team is seeking references to other methods of selective ionization of freon or other tracers in mixture with air. Methods of application will be studied as processes come to light.

And, finally, the search of the literature and the state-of-the-art survey will continue.